OBJECT LESSONS

IN

ELEMENTARY SCIENCE

OBJECT LESSONS

IN

ELEMENTARY SCIENCE

FOLLOWING THE SCHEME ISSUED BY THE
LONDON SCHOOL BOARD

BY

VINCENT T. MURCHÉ
HEADMASTER OF BOUNDARY LANE BOARD SCHOOL, CAMBERWELL;
AUTHOR OF BLACKIE'S 'PHYSIOLOGY,' 'BOTANY,' ETC.

VOL. III

MACMILLAN AND CO., LIMITED
ST. MARTIN'S STREET, LONDON, W.C.
NEW YORK: THE MACMILLAN COMPANY
1898

First Edition July 1894
Reprinted with corrections October 1894, 1896, 1898

PREFACE

Some years ago the London School Board issued a Scheme of Object Teaching in Elementary Science. This Scheme was at once adopted by the compiler of these Lessons for use in his own school. He started by writing complete Notes of the Lessons, based on the Scheme, for each section of the school; and has exercised much care and thought in getting together a museum of suitable objects for illustrating the teaching.

The result has been a marked success—the teachers as well as the children deriving pleasure and benefit, and looking forward to the lessons as a welcome break in the monotony of the school routine.

H.M. Inspector has always shown his commendation of the work; and in July last he brought the Right Hon. A. H. D. Acland, the Vice-President of the Council, on a visit to the school for the purpose of witnessing the teaching in this subject.

The Vice-President spent about an hour and a half with the various classes, showed great interest in the work, examined the books of written lessons, and himself suggested the advisability of publishing them. Hence they now appear in book form.

A special point in the arrangement of the Lessons is that they are all written in full, no single step being left unexplained. The pupil-teachers can therefore be allowed to take their share of the work, to their own benefit and improvement, without loss to the children.

The instructions to the teachers are printed in italics, the salient points of the lesson are conspicuously shown in the change of type, and lists of suitable objects for illustrating each lesson are placed at the end of the book.

As the books are intended for the teacher and not for the class, there is no need for copious illustration. The plates at the end are intended for reproduction as black-board sketches, and generally for the guidance of the teacher. The teacher will reproduce on the black-board as much as he can of each sketch, according to his individual skill with the chalk.

The universal complaint from Inspectors in all parts of the country has been that the so-called "Object Lessons" too often fail in their purpose, because nothing is so conspicuous as the absence of the objects themselves. The main purpose throughout this course has been never to use a picture where the real object can (with a little trouble) be obtained; and the Author has found, and still finds, that the teachers as well as the children take a lively interest in adding to the stock of articles in the school museum.

The various stages are written up to the possibilities of a school of good repute, well appointed and staffed. In schools not so fortunately placed, a rearrangement of the

Standards might be made—Standards I. and II. taking the course prescribed here for Standard I., and so on.

In smaller schools, and girls' schools, the lessons dealing with Animal and Plant Life alone would make an interesting and useful course; or the lessons on Common Objects (Standards I.-III.) might be followed in the higher Standards by the course in Mechanics, Botany, Zoology, or Chemistry, at the teacher's pleasure.

The complete course covers almost the entire ground of alternative subjects prescribed by the Code of 1894.

The Author begs to acknowledge his indebtedness to Mr. Rick's admirable book, *Object Lessons and How to Read Them;* also to *The Chemistry of Common Life; Animal Products; Strength of Materials and Structures; Dictionary of Manufactures;* and for trade statistics to the researches of friends

SCHEMES OF LESSONS

STANDARD V

I. Lessons from Mechanics (Boys only)

Matter in three states—solids, liquids, and gases. Mechanical properties peculiar to each state. Matter is porous, compressible, elastic. Measurements as practised by the mechanic. (The instruction to be purely descriptive and experimental.)

Ia. Lessons from Domestic Economy (Girls only)

Food; its composition and nutritive value. Clothing and washing.

II. Lessons from Heat (Boys and Girls)

1. Distribution of heat—conduction, radiation, convection.

(*a*) Conduction—good and bad conductors. Clothing.

(*b*) Radiation—good and bad radiators. Radiation and absorption. How heat affects the absorption of watery vapour by the atmosphere. The formation of dew and hoar-frost.

(*c*) Convection—boiling and the boiling point. Effect of pressure on the boiling point. Distillation. Steam and the steam-engine.

2. Heat, the cause of motion in the air. Winds. Ventilation.

3. Heat, the cause of currents in the ocean.

4. Specific heat.

III. Lessons from Biology (Boys and Girls)

1. Economic products of plants. Preparation and uses of cotton, flax, opium, quinine, indigo, olive-oil, palm-oil, resin, turpentine, india-rubber.

2. Introductory lessons on physiology—bones and joints. Locomotion in mammals, and adaptation of bones for same. Teeth of mammals; the chief peculiarities. The skin and its function. Cleanliness. Coverings of animals—hair, fur, wool.

STANDARD VI

I. Lessons from Mechanics (Boys only)

1. The simple mechanical powers—lever, wheel and axle, pulley, inclined plane, wedge, screw. (To be illustrated by working models.)

2. Liquid pressure—the hydrostatic press.

IA. Lessons from Domestic Economy (Girls only)

Food; its functions. The dwelling—warming, cleaning, and ventilation.

II. Lessons from Chemistry (Boys and Girls)

Elements and compounds. Chemical combination and mechanical mixture. Simple notion of common processes. The air, a **mixture** of gases. Water, a **compound** of oxygen and hydrogen. Combustion. Its products. Some knowledge of the more important non-metallic elements—oxygen, hydrogen, nitrogen, chlorine, carbon, sulphur, phosphorus. Acids, alkalies, and salts—meaning of.

III. LESSONS FROM BIOLOGY (BOYS OR GIRLS)

1. Geographical distribution of plants and animals most useful to man. Trade and commerce arising therefrom.

2. General structure and function of the lungs, heart, blood-vessels, stomach, intestines, liver, and kidneys. Chief peculiarities and changes of these organs in the vertebrates.

CONTENTS

STANDARD V

STANDARD VI

STANDARD V

STANDARD V.

LESSONS FROM MECHANICS.

(BOYS ONLY)

Lesson I

MATTER

I. Existence of Matter

Show a brick or any common object. Make the class describe it, as to its size, colour, and shape.

How do we learn thus much about the brick? Our eyes tell us; that is, we learn **through the sense of sight.**

Hand the object round, and make the class tell that it is hard and rough.

This we learn **through the sense of touch.**

Take two bottles, one containing paraffin, the other water.

Here we have two things which neither our eyes nor our sense of touch will help us to distinguish.

What would be a good way to find out? Smell the two bottles. Quite right. Here we rely upon another sense, **the sense of smell,** to tell us how to distinguish the two bodies.

Here are two pieces of white substance—one is sugar, the other salt. Our sense of sight tells us that they are

very similar in shape, size, colour, and general appearance, so that we cannot tell one from the other. When, however, I put my tongue to each, I soon learn to distinguish them; and this time, through another sense—**the sense of taste.**

Everything around us which appeals to us in this way, through one or more of our senses, we call **matter.**

By the name **matter,** then, we mean **every substance that exists; every substance about which we may learn through our senses.**

The air around us is matter. We know that it has an existence, for although we can neither see, smell, nor taste it, we can hear it when it is in motion, and we can feel it as it rushes through our mouth and nostrils in the act of breathing.

II. Matter is indestructible

Place a small piece of gun-cotton in the palm of the hand and apply a light. There will be a sudden flash; the substance will burn so rapidly that the hand will scarcely feel the heat, and every particle of it will disappear.

What has become of the gun-cotton? It has not been destroyed; it has simply been converted into another form, and has passed away in the air as an invisible gas.

Consider the burning of a candle or a lump of coal in the grate, and make the class tell, by referring to some of the earlier lessons, what actually takes place.

The candle contains **matter** in the form of tallow and wick. These substances, as well as the coal, are formed of hydrogen and carbon. The burning simply uses the **hydrogen** to form a new substance, **water**; and the **carbon** to form another new substance, **carbonic acid gas.**

Nothing is destroyed. The coal and the tallow are changed into new forms; that is all.

What happens when we dissolve salt, sugar, alum, soda, etc., in water. These substances disappear. They seem

to be destroyed. They are not destroyed; we know they *are there still, for we can recover them easily by evaporating the water.*

It is just so with every kind of matter that exists. We may grind it into powder, dissolve it in water, and even burn it, but we cannot get rid of it—we cannot destroy it; we merely change its form.

Matter is indestructible.

III. Matter is made up of Molecules

Rub two pieces of sugar, salt, or chalk together.

What is the result? The substances fall apart in small grains.

Put some of the salt or sugar into water and it disappears entirely.

What does that mean? The substance has been broken up, in the water, into such extremely minute particles that they can no longer be seen. Even the microscope would be unable to detect them.

Pour one drop of olive-oil into a test-tube filled with water, and shake the vessel well for a minute.

What becomes of the oil? Instead of the single drop there are now hundreds of tiny drops or particles which may be seen making their way upwards towards the surface of the water.

Let fall a tiny drop of mercury on the table, or on some dark surface, and watch how readily the one little drop breaks up into smaller and smaller particles.

Repeat the experiment of heating mercury in a test-tube till it boils and passes off in vapour form.

We cannot see the vapour; how do we know it is passing away?

Collect it, by making it condense on some cold, rough surface held over the tube.

When we examine this, with the help of the magnifying glass, we shall find it covered with extremely minute silvery balls, too small to be visible with the naked eye.

Now what does all this tell us? That matter can be broken up into **extremely small particles.** We saw the particles of the grated sugar, salt, and chalk, and the little globules of oil and mercury. In the case of the mercury-vapour those particles were so small as to be absolutely invisible, and it was only after condensation had united a vast number of them into the form of little, tiny balls that the magnifying glass was able to detect them.

What is the name we give to these extremely small particles of matter? We call them **molecules.**

IV. Solids, Liquids, and Gases

Lead the class to tell, by referring to past lessons, the characteristics of the three states of matter.

1. **Solids** are bodies that have a **fixed shape** of their own, and always **occupy the same space.** They **resist any attempt to alter** either their shape or size. Neither shape nor size can be altered, unless these bodies be acted upon with much force.

2. **Liquids** are bodies which keep their own size or volume, resisting very powerfully any attempt to alter their size. In this they resemble solids.

They have **no shape of their own,** always adapting themselves to the form of the vessel which holds them, and spreading themselves out so as to keep a level surface.

3. **Gases** are bodies which have no fixed form or volume. If a gas be put into a vessel, it occupies the whole space of the vessel, but it differs from a liquid in that it has no surface. **Gases can always be compressed into a smaller space** than they once occupied.

The children themselves should be made to recapitulate all these facts, and, with the occasional help of the teacher, to illustrate them with familiar objects. The teaching of the earlier lessons will have made this an easy matter now.

V. The Cause of these Characteristics

The various solid bodies just dealt with, if placed on the table, would rest there for an indefinite period unchanged in shape and size. So too would the liquids as long as they were held in some vessel. But immediately we pour them out of the vessel they flow away.

A gas, unless it be kept confined, will rapidly spread and diffuse itself through the room.

What is that force which enables the brick or any solid body to retain its shape? **Cohesion.**

Solids, liquids, and gases are **all made up of molecules.**

In all solid bodies the molecules are held together by this force; so that each individual molecule has its own particular position, from which it cannot be moved **except this force of cohesion be first overcome.**

This force is **not equally strong in all solids.** We can break a piece of lead more easily than a piece of steel, a brick more easily than a piece of marble; why?

In liquids the force of cohesion is **slight as compared with that of solids.** The molecules have no fixed position, but are free to move about and roll and tumble over one another. This is why liquids flow when unsupported.

Yet even liquids differ in the amount of cohesion they possess.

Illustrate with such liquids as **water, treacle, or tar.**

Why would it be easier to thrust one's hand into a basin of water than into a basin of treacle, tar, or mercury?

Why does the liquid always keep a level surface?

Lead the class to tell of the force of gravity acting on the molecules of the liquid, all being free to move in response to the force. All are acted upon equally; hence the level surface.

In gases there is **no force of cohesion,** but rather **a repelling force.** This is why the molecules of a gas are

constantly trying to separate farther and farther from each other. Gas escaping from the burner in one part of the house, or at one end of a large room, may soon be detected in the other.

Lesson II

GENERAL PROPERTIES OF MATTER

THERE are certain properties which all matter of every kind possesses. We speak of these as the general properties of matter. They are **extension, divisibility, weight, compressibility, porosity, elasticity.**

I. EXTENSION

Fill a glass with water, and into it drop a large stone.

Some of the water overflows. If we remove the stone, the water will fall in the glass, showing how much was driven out.

Why was it driven out? To make room for the stone. The amount of water driven out would have occupied exactly the space which the stone required.

The water and the stone cannot occupy the same space at the same time.

Drive a nail in a piece of wood. The nail gets in only by thrusting aside the particles of the wood. It would not be possible for the wood and the iron to occupy the same space at the same time.

Tell that what is true in these two cases is universally true. Every kind of matter—solid, liquid or gas—must occupy a certain amount of space or room; **no two bodies can occupy the same space at the same time.** *This is the meaning of the property known as* **extension.**

II. Divisibility

Our last lesson showed us that matter of all kinds is composed of minute particles called molecules, and can be separated or divided by various means—sometimes by mechanical grinding, sometimes by dissolving, sometimes by boiling and evaporating.

Drop a small piece of some powerful dye into a vessel of water, and the whole of the liquid will soon be coloured. The least drop of it would, if removed from the rest, retain the colour. Imagine such a vessel to contain 10,000 *such drops, and it is evident that the piece of dye must have been divided up into at least ten thousand particles.*

This is what we mean by **divisibility**. It enables man to reduce all bodies to any required size. On the other hand, it is this property that causes bodies to wear away; even the rocks wear away by reason of it, and become loose particles of dust.

III. Weight

Refer to the earlier lessons, and make the class explain (1) *what we mean by saying that all bodies have weight;* (2) *what gives them weight;* (3) *why a drop of water poured from a glass falls down, and not up, and so on.*

We know that solids and liquids have weight. We can feel the muscular exertion of holding them in the hand. It is equally true of gases, although it is not so easily detected.

Take an air-tight, stoppered glass bottle; exhaust all the air from it by means of the air-pump, and weigh it. Now remove the stopper, allow air to enter the bottle, and weigh it again. We find it is heavier now.

What makes it heavier? The weight of the air in the bottle.

Tell that if the bottle could hold just 100 *cubic inches, the increase of weight would be exactly* 31 *grains,* i.e. 100 *cubic inches of air weigh* 31 *grains.*

If we had filled the bottle with **hydrogen** instead of air, the increase of weight would have been **only 2 grains.** But this shows us that even **hydrogen,** the lightest of all bodies, **has weight.**

Balloons filled with hydrogen rise in the air, because the air, being heavier than hydrogen, forces them upwards and makes them float.

IV. Porosity

This property must now be quite familiar to the class. Make them tell all they can of the nature of **pores.** *They are the spaces between the molecules of which the substance is made.*

Sometimes we speak of a body as having **sensible pores.** What does this mean?

Make the class mention substances which possess **sensible pores,** e.g. *sponge, bread, charcoal, pumice-stone, wood, cane, etc.*

Sometimes we cannot actually see the pores in a body. How can we find out whether it is **porous** or not? Put it in water. If it absorbs water, it must be porous.

Make the class tell how to show this with a piece of chalk, lump-sugar, salt, or brick. The children might be allowed to demonstrate these proofs themselves, as they have been shown.

A very pretty experiment may now be shown if an air-pump be at hand.

Take a piece of thick malacca cane; point one end, and hollow out the other, so as to form a sort of cup. Place the cane in the open mouth of the receiver, with the pointed end downwards, taking care to see that it fits air-tight. Fill the little cup with mercury, and then exhaust the air from the receiver. In a short time a shower of tiny drops of mercury will be seen falling from the lower end of the cane which is within the receiver. **The pressure of the air from above drives the mercury downward through the pores of the cane.**

A piece of metal, say copper or steel, does not look very porous. We could not detect any pores in it with the most powerful microscope. But what would happen

to it if it were placed in a freezing mixture of salt and snow? It would shrink up or contract with the cold. Why? Because **the molecules would be driven close together.** This proves conclusively that the iron and the copper under ordinary circumstances are porous. There are spaces between their molecules—these spaces are the pores. **We call such pores**[1] **physical pores.** Every solid substance is more or less porous—some more than others. **Liquids** are porous as well as solids, although, in this case again, it is impossible to detect the pores.

Take two tumblers. Fill one to the brim with water, and put a quantity of salt in the other. Carefully pour the salt from the one tumbler into the water in the other, and watch it dissolve. Stir it gently so as not to spill a drop of the water.

Presently show what bulk of salt has disappeared from the one tumbler.

But how could it have found room in the other without causing some of the water to overflow? If a similar quantity of water, instead of salt, had been poured in, there would have been an overflow. The salt has found room **by simply filling up the spaces or pores between the molecules of water.**

Similarly if a pint of alcohol were mixed with a pint of water, we should get, not a quart of the mixture, as we might expect, but considerably less than a quart. Some of the alcohol finds its way into the pores between the molecules of the water.

V. Compressibility

Squeeze a piece of sponge or a piece of new bread in the hand. We find we can press it into a very small bulk. We say it is **compressible.**

What kind of substances are the sponge and the bread? Porous substances.

Lead the children to see that these things are **compressible**

[1] The shrinkage shows the diminution in size of the molecules themselves, of the spaces between them, and possibly of both.

simply because they are **porous.** *The pressure brings the molecules closer together; and* **the more porous** *a body is* **the more compressible** *it must be. The most compressible bodies are gases, which are also the most porous, because their molecules are at a considerable distance from one another.*

Tell that it is quite possible to squeeze 100 *gallons of air into the bulk of a single gallon.*

Just as solids vary in porosity, so do they vary in compressibility. Some, such as wood, cork, bread, sponge, are very compressible; others, such as glass, are very slightly compressible,—pressure will rather reduce them to powder than lessen their bulk.

Show a coin, calling attention to the impression on it.

Explain that this proves the metal to be compressible, because the impression was made by pressing the molecules closer together.

Liquids have less compressibility than any other bodies.

Tell that it has been proved that 20,000 *cubic inches of water cannot be reduced by the utmost pressure to a less bulk than* 19,999 *cubic inches. That is, it loses only one cubic inch in* 20,000.

Let the children repeat the simple experiments with the syringe or squirt, to show that water resists compression.

VI. Elasticity

Lead the children to describe this property. It is the power which some bodies have **of springing back to their former shape after they have been interfered with.** *It is a common property of both solids, liquids, and gases.*

Make the class mention some substances which are elastic and others which are not.

Show the elasticity of such common objects as sponge, cork, and wool; cane, whalebone, a steel watch-spring; india-rubber, flannel, or cloth.

Make the class describe the different kinds of elasticity.

Some bodies show their elasticity after being squeezed;

others after being pulled; and others only when they are bent.

Throw a child's air-balloon on the table.

It flies upward. Why?

Tell that when the balloon strikes the table it becomes flattened, and the air in it is compressed. The air, however, is **elastic,** *and springs back at once, to regain its original bulk.*

It is the springing back of the air that causes the balloon to fly upward.

Smear a smooth, polished, flat stone with oil or ink, and let fall on it a glass marble, catching it as it rebounds. The marble touches the surface of the stone only at one little spot, as may be easily shown. Yet when we look at the ink on the slab, we find that it shows a large circular mark. The fact is, the marble, in striking on the slab, became flattened, and in that flattened condition the mark was made. **Its own elasticity, however, caused it to spring back at once to its original shape, and the springing back gave it the upward rebound.**

Lesson III

MEASUREMENT AS PRACTISED BY THE MECHANIC

I. INTRODUCTION

LEAD the class to talk about the subject of the last lesson, so far as the property of extension is concerned.

When we say that every kind of matter possesses **extension,** what do we mean? We mean that everything that exists occupies some amount of space or room.

We sometimes consider the extension of matter **in one direction only.** This constitutes **length.** Sometimes we require to know its extension in two directions, **length and breadth,** and we then speak of its **surface.** Sometimes again it is necessary to consider its extension in

three directions, **length, breadth,** and **thickness**; this gives us the **volume** or **space** occupied by the body.

II. Measurement of Length

1. Ancient modes of measuring.—People soon began to find it necessary, in dealing with matter of any kind, to get a correct idea of its size. In very early times people seem to have made use of the hand, arm, and foot as natural measures, and perhaps they then found them convenient enough, for they were always sure of having them ready when they were wanted.

Among the commonest of these ancient measures were:—

The span, *i.e.* the distance which can be stretched between the thumb and the little finger.

The cubit, *i.e.* the length of a man's arm from the point of the elbow to the extremity of the middle finger.

The foot, *i.e.* the length of a man's foot.

The inch, *i.e.* the breadth of the thumb.

The fathom, *i.e.* the length of the outstretched arms from the tips of the fingers.

Boys nowadays in their games frequently span distances with the hand, or measure or step them with the feet, and not unfrequently come to quarrelling, because of these measurements. Why? Because boys' feet and hands are not all the same size, and such measurements cannot be fair and exact.

As it is with boys, so it has been always with men. These rough-and-ready methods of measuring with hand, foot, and arm must have often caused disputes. Hence, in course of time, people, while retaining the old names, began to give to each a certain definite length, and that length was fixed by law.

For example, the average length of the **span** is 9 inches, and of the cubit 18¼ inches. When therefore we read in the Bible of the cubit and the span, we know that

the Jews meant by each of these measurements an actual, recognised, and fixed length.

In like manner, when the Greeks and Romans fixed upon the foot as their unit of measurement, they meant by it, not the length of any man's foot, but a certain fixed length, settled by law.

The Romans divided their foot into 12 equal parts, which they called **unciæ** (twelfths), and from this we derive our own word **inch,** the twelfth part of our foot.

The French afterwards adopted the foot as a unit, and are said to have taken the measure of the foot of their famous king, Charlemagne, for this purpose. Henceforth this foot became for them a fixed definite unit of length.

The Saxons adopted the length of a man's **gird** or **girdle** as their unit measure of length, and called it a **yard** or **gird.**

Men, however, differ very much in their measurement round the waist, and hence, to prevent mistakes and disputes, a certain length was fixed upon for this yard, and the true measure was kept at the royal capital, Winchester.

In the time of Henry I. another unit was taken from the length of that king's arm, and the old name **yard** was given to it. This yard has been the English standard of measure ever since.

2. **The present standard unit.**—In the House of Commons is kept a long bronze bar, one inch in thickness, with a plug of gold let in near each end. Through the centre of each gold plug a fine cross-line is cut; and the Imperial Parliament have passed a law declaring that the distance between the two fine cross-lines shall be the true **yard.** We call it the **imperial yard.**

Show how strict the law is in ensuring correct measurement. It states that the bar is always to be measured at one temperature, 62° Fah.

Make the class tell that metals expand with heat and contract with cold; hence the precaution.

Tell that copies of this imperial yard may be seen at the

Royal Mint, Royal Observatory, Greenwich, the Royal Society, and the Court of Exchequer.

From the **yard,** as the **standard unit,** all other measures are taken.

Make the class give the various multiples and sub-multiples of the yard.

III. Instruments used in measuring Length

1. **The two-foot rule.**—For ordinary measurement the mechanic uses a two-foot rule.

Show one and let the class describe it.

It is a perfectly straight and rigid stick of hard box-wood, and it is fitted with a brass joint in the middle, so that it may be folded small enough to go into the workman's pocket. On the face of the rule the inches are marked and numbered; and each inch is further sub-divided into half-inches, quarters, eighths, and sixteenths.

2. **The tape-measure.**—*Show one of these; describe it and tell how it is used.*

It is employed in measuring long lengths, where a two-foot rule would be tedious and inconvenient. It is particularly useful in measuring circular bodies.

Illustrate by taking the circumference of the globe, a jug, a ball, or any object with a rounded surface.

Try to do the measuring also with the rigid rule.

3. **The compasses.**—All are familiar with the use of this instrument in the drawing lessons.

Tell that the mechanic mostly uses compasses in setting off a certain fixed length on the material he is working.

4. **The calipers.**—*Show these, and explain how they are used. They are employed mostly in ascertaining the internal and external diameters of cylindrical bodies.*

5. **The wire-gauge.**—This is simply a steel plate, with a number of slits of different widths cut round its edges. The width of each slit is known and numbered, and the diameter of a wire which exactly fits one of them is known too.

IV. Measurement of Surface

Let us commence by measuring the surface of this blackboard. If we take our rule and measure along one edge, we shall find that it is three feet long. Set off these divisions on the board. Now measure the adjacent edge, and we find that is two feet. Mark this also. We call one measurement the **length,** *the other the* **breadth** *of the board.*

Do the same on the opposite sides, and join the points by straight lines across the board.

What have we done? We have divided the board into squares.

What is the length of the side of each square? A foot.

A square whose side measures a foot is called a square foot.

Now, how many squares have we? Six. The whole surface of the board, then, contains six square feet.

We might have told the area or surface of the board at once without drawing the lines, merely by multiplying the length by the breadth; thus $3 \times 2 = 6$.

Pass on next to the surface of the table, the floor, and the wall of the room, etc., of course avoiding inches altogether at first. Let the children measure and calculate for themselves the covers of their books, some sheets of paper, their slates, etc.

V. Measure of Volume

Volume means, as we have seen, length, breadth, and thickness.

The measurement of volume should be shown graphically with the help of a number of inch cubes.

Show a single cube first. It is one inch long, one inch broad, and one inch thick. Just as we called the surface inch a square inch, **we now call this a solid or cubic inch.**

Make it clear that in a square inch there is not the smallest thickness; it is mere surface, nothing more.

Hence all matter must have thickness, as well as length and breadth.

Now build up the cubes in various forms—say three in length, three in breadth, and three in depth or thickness.

Let one of the class now come to the front and separate the cubes, counting them as he sets them aside.

How many does he find? Twenty-seven.

Proceed next to make other combinations—say three in length, two in breadth, and two in depth; or two in length, two in breadth, and two in depth; and have them removed and counted each time.

With a little help the class will now be able to see what it all means. In the first case, the block of cubes contained 27 *cubic inches. That was* $3 \times 3 \times 3 = 27$. *In the next instance it contained* 12 *cubic inches,* i.e. $3 \times 2 \times 2 = 12$. *And in the last it was* 8 *cubic inches,* i.e. $2 \times 2 \times 2 = 8$.

LESSONS FROM HEAT

Lesson IV

DISTRIBUTION OF HEAT—CONDUCTION

We have already learnt something about heat and its effect on various bodies—solids, liquids, and gases. Our next business will be to inquire how heated bodies part with their heat, *i.e.* how heat passes from one portion of matter to another.

I. Conduction

Place the poker in the fire, and in a short time, not only will the one end grow red hot, but the opposite extremity will become hot too.

How does this part of the poker, which is out of the fire, become hot? **The heat from the fire travels**

along the poker, from particle to particle, until it reaches the opposite end.

Join a thin bar of copper and one of iron, end to end, and fix the joined ends in the flame of the Bunsen burner or the spirit-lamp. Place a piece of phosphorus on the opposite extremity of each. In a short time the phosphorus on the copper bar will take fire; but that on the iron will remain much longer before it ignites.

What do we learn from this? **That heat travels along the particles of both the copper and the iron; but that it travels more rapidly along the former than the latter.**

Place a thin strip of copper and a piece of bone in the evaporating dish over the spirit-lamp. After a few minutes let one of the boys come forward and take hold of the end of each, one by one.

The copper has become so hot that he quickly drops it; but he can easily pick up the bone, it is not heated except in the spot where it has been in contact with the dish.

Thus we learn that **heat travels rapidly along the particles of copper, but very slowly indeed through bone.**

Copper and iron carry or **conduct** the heat from particle to particle of their substance.

We say that these metals are **good conductors of heat**; and that heat travels along them by **conduction.**

The bone conducts heat so slowly that we usually call it a **non-conductor.**

II. Conductors

Tell that what is true of the substances we have named is equally true of all substances. They may be arranged in one or other of these three classes—**good conductors, bad conductors, non-conductors.**

Place a metal plate and some pieces of marble, stone, brick, wood, cork, leather, and wool in ice. Remove them, and lay the hand on each in succession.

They are all at the same temperature—that of the ice. The metal produces **an intense sensation of cold**; this is less severe with the marble and stone; less still with the brick and wood; while the leather, cork, and wool feel almost warm in comparison. Why is this?

Explain—1. *That each of these substances is colder than the hand.*

2. *That each robs the hand of some of its heat.*

3. *That the metal, being the best conductor, takes away the greatest amount of heat from the hand; the other substances taking less and less in proportion to their lower conducting power.*

4. *That the hand feels the sensation of cold in proportion to the amount of heat abstracted.*

Place the same substances in hot water, and proceed in a similar way. The metal now feels hotter than the other substances; the leather, cork, and wool convey least heat.

Show that the explanation in this case is the same as before, and depends on the difference in the conducting powers of these different bodies.

In arranging bodies according to their conducting power, we find that **dense substances** are generally **the best conductors; light porous ones the worst.**

Conduction may be said to be **confined to solid bodies**; liquids and gases being very bad conductors of heat.

The metals are the best conductors of all, but they differ very much one from the other. They stand thus in the order of their conducting power:—**silver, copper, gold, brass, tin, iron, lead, platinum,** and **bismuth**—silver being the best.

Among the bad conductors are **marble, stone, brick, glass, earthenware, sealing-wax, leather, wood, linen, cotton,** and **straw.**

The non-conductors include **bone, horn, feathers, down, fur, wool, flannel, silk, hair, cork, india-rubber.**

III. The Importance of this Knowledge

1. It was the knowledge of this superior conducting power of metals that enabled Sir Humphrey Davy to make his safety-lamp.

Refer to the earlier lesson on this subject, and help the class to tell the nature of the wire-gauze covering, and how it owes its usefulness to the conducting power of the metallic wire. The explosive gases pass through the gauze and burn there; but the flame instead of passing outside is dissipated or conducted away by the wire.

2. Stone is a better conductor than brick or wood. Hence a stone house (unless the walls are very thick) is colder in winter and hotter in summer than one built of brick or wood.

See that the reason in each case is clearly understood.

3. Ice-houses (or pits) are built of brick and thatched with straw, because the low conducting power of brick and straw prevents the warmer air around from acting on the ice. In the hot summer weather, too, **the ice is wrapped in flannel and covered with sawdust.** Why?

4. Fire-bricks are much used for lining the backs of stoves. They are very bad conductors; they prevent the heat from escaping backwards into the chimney.

5. Metal kettles, tea-pots, coffee-pots, and other vessels for cooking and boiling purposes usually have their handles made of bone, horn, wood, or some other non-conducting substance; and if not, we are always careful to make a thick pad of flannel, cloth, or paper to serve the same purpose.

6. In the same way all tools which have to be made hot, *e.g.* soldering and branding irons, are provided with wooden handles.

7. We keep our tea hot on the table without any fire, by merely covering the tea-pot with a cosey made of wool or feathers.

Tell the reason for this; explain that this is the very reason

why we in winter clothe ourselves in **non-conducting dresses,** *such as* **fur cloaks, flannel,** *and* **other woollen garments.**

These are not warm in themselves; they merely act as non-conductors, and prevent the heat from passing away out of our bodies.

In the heat of summer when we wish to be cool, we exchange our furs and flannels for light, thinner materials **of higher conducting power,** which allow some of the heat of the body to escape into the air.

Lesson V

DISTRIBUTION OF HEAT—CONVECTION

I. Introduction

Make the class tell, by way of introducing the new teaching, all they can of the conduction of heat.

This mode of conveying heat is confined to solids. Their molecules or particles have a certain fixed relative position which never alters.

What name do we give to the force which holds the molecules together? We call it cohesion.

The heat affects one molecule, and is passed on from that to the next, and so on.

The molecules themselves do not move, or change their position in any way.

We shall now notice the way in which liquids behave when heated.

II. Boiling

Take a large test-tube; place a piece of ice in the bottom, with something (say a knot of wire forced down upon it) to keep it in position. Fill the tube nearly to the top with water.

Why do I press the ice down with the knot of wire? Ice is lighter than water, and would rise to the top. The wire is to keep it at the bottom of the tube.

Let the tube be now held obliquely over the flame of the spirit-lamp, so as to heat the upper part of the tube and the liquid inside. In a short time the water will rise in temperature, and continue to do so until it is made to boil.

Let the class see that the water in the upper part of the tube is actually in a state of ebullition. Test its heat. Note the steam-vapour.

But what do we see in the bottom of the tube? The ice remains in it unmelted. The tube itself and the water in it are as cold as they were at first.

It would in fact take hours before the heat would have made any sensible difference in the water below the flame.

The heat has readily passed upward, but it cannot descend.

Now this proves that the heat did not travel through the liquid by **conduction,** because **conduction** acts downwards as well as upwards, horizontally or obliquely as well as vertically. It is quite unaffected by the position of the body through which it moves.

Had the heat been **conducted** through the water, the lower part of the liquid would have become as hot as the upper—the ice would have quickly melted.

Water and liquids generally are bad conductors of heat.

Transfer the lamp-flame now from the upper part of the tube to the lower end, and let the class watch the result.

The water is rapidly heated, **the ice melts and disappears,** and in a few minutes the **whole of the liquid** in the tube **will be seen to boil.**

The whole of the liquid has become uniformly heated, because the heat has travelled upwards from bottom to top.

Let us see if we can find out how heat travels in liquids.

III. Convection

Take a large glass flask, and nearly fill it with water; drop into the water a few pieces of solid blue litmus; and apply the

flame of the Bunsen burner or the spirit-lamp to the bottom of the flask.

Almost at once will be seen an upward central current of water, rendered distinctly visible by the blue colouring matter of the litmus. The current rises immediately above the spot at which the flame acts on the bottom of the flask, till it reaches the surface of the water.

Here it bends over in every direction, forming a great number of descending currents along the outer wall of the flask.

These continue to travel downwards, until they reach the heated lower portion of the flask, when they again ascend as before.

Now let us see if we can understand what is actually taking place.

First, what is the great difference between the molecules of a liquid and those of a solid? The molecules of a liquid have little or no cohesion; they are free to move about in any direction. Those of a solid are fixed and stationary.

The molecules of the water, which were at first quiet, were set in motion by the heat, in some way, so that the whole of the liquid was soon in rapid circulation. The particles of water themselves moved upwards, outwards, and downwards.

But we want to find out why this is the case.

We have already learned something about the way in which water acts in cooling. The particles on the surface, of course, first feel the effect of the cooling process.

How do they act? They contract and become denser and heavier than the particles below them.

What then happens to the lighter particles? They rise to the surface, while the heavier ones sink.

Why are they lighter? Because they are warmer.

Now let us go back to our flask. The flame heats some of the particles near the bottom of the flask. The heating makes them **expand and become lighter** than those around and above them.

There can only be one result; what is that? The heated, expanded particles **rise to the surface.**

It was the stream of these rising particles that formed the central current which the colouring matter enabled us to see.

But we have not done yet. Think of this stream of heated particles rising through the cold ones all round them.

What must happen as they rise? **They give out their heat** to the colder ones as they pass upwards, and by the time they reach the surface **they themselves are cold.**

But all this time more and more particles at the bottom of the flask have been heated by the flame, and these continue to rise and force the others onward.

Hence it happens that those that were heated at the bottom and have reached the surface are now cooler and heavier than the others, and being heavier, as well as being forced onwards, they move in the only direction possible—that is, **downwards along the sides of the vessel,** there to meet again at last the heat of the flame, and rise again as before.

Thus we see that in water the heat is **carried** or **conveyed** by the particles of the water themselves. The heated particles rise through the whole mass, and, as they rise, give out their heat to the rest. This method of **carrying** or **conveying** heat is called **convection.**

As the temperature of the whole of the liquid rises, the heat at the bottom converts the little particles of water into **particles of steam.**

These are lighter still than the heated particles of actual water—they are extremely light. They rise in little **balls or bubbles** through the water.

At first the water robs them continually of their heat, and **they burst as they rise**; but after a time, as the water itself becomes hotter, the bubbles reach the surface without bursting.

It is **this bursting of the steam-bubble** on the top which **makes the commotion** as water boils.

Lesson VI

BOILING

I. The Boiling Point of Liquids

Boil some water in an ordinary flask over the Bunsen burner or the spirit-lamp. Stand a small thermometer in the flask, and show the gradual rise of the mercury as the water increases in heat. When ebullition sets in, note that the thermometer registers 212° *Fah.*

Show that however much more heat is added now, there will be no further rise in the mercury. **The boiling water will continue to register 212°; the steam which passes off from it will also register 212° Fah.**

Take another flask and substitute spirits of wine for the water. In this case the thermometer gradually rises to about 172° *Fah., and at that point ebullition commences.* **No further rise will take place; and while the thermometer continues to register 172°, the alcohol will boil, and pass off as invisible vapour.**

Common ether will boil, and pass off as vapour, at about 98° Fah.; in other words, the heat of the sun on an ordinary summer's day is sufficient to boil ether.

Take next some water saturated with salt, i.e. *holding in solution as much salt as it can dissolve. Set it over the flame to boil.*

This strong brine, instead of boiling at 212° Fah., will not boil till it reaches nearly 230° Fah.

Spirits of turpentine rises to nearly 270° Fah. before boiling sets in.

Mercury does not boil below 660° Fah.

The point at which various liquids boil is called their boiling point.

II. Distillation

What happens if I hold this cold slate over the steam as it issues from the water boiling in the flask?

The steam (or water-vapour) is reconverted into drops of liquid water.

If I boil mercury in a test-tube, it will pass off too in invisible vapour, and we may collect it again on a cold surface in tiny round globules of liquid metal. It is so with all these boiling liquids.

What do we call this process of reconverting the vapour into a liquid? It is known as **condensation.**

What causes the condensation? The vapour is condensed into liquid **by being robbed of the heat which it contained.** The water is first evaporated, or changed into vapour, by the addition of heat; **it is changed back again into the liquid form (condensed) as soon as that heat is taken away from it.**

When the invisible vapour comes into contact with the cold slate, it parts with some of its heat; and the loss of heat thus causes its molecules to contract and crowd together till it assumes the liquid form again.

Let us illustrate this in another way.

Take some of that strong brine which I showed you just now. We will boil it in the retort. I don't wish the steam to escape, so I will fit the neck of the retort into the mouth of this flask. The flask itself I will stand in this basin of ice-cold water.

Place the flame of the burner under the retort, and watch the result.

What is the heat doing to the liquid in the retort? It is heating and boiling it.

What happens when liquids boil? They become converted into invisible vapour.

What becomes of the vapour in this case? It passes into the flask.

The sides of the flask are very cold—they are surrounded by very cold water. How will this affect the water-vapour inside? The vapour will be reconverted (condensed) into liquid-water again.

We call this double process, of evaporating the

liquid into vapour, and changing the vapour back again into liquid—distillation.

Remove the flask from the retort; pour out some of the water, and let one of the class taste it.

Is it brine now? No. It is pure water. **The salt was all left behind in the retort. We call this distilled water.**

Tell that the same might be done with solutions of sugar, alum, soda, lime, or any other soluble substance. We should in each case get only pure distilled water in the flask at the end of the process.

III. The Art of Distilling

The variation in the boiling points of different liquids is turned to useful account in the art of distilling. An apparatus called a **still**, and formed on the principle of our retort and flask, is used for the purpose.

Instead of the retort is a strong copper vessel, in which the liquid is boiled. The distilled vapours are passed through a long spiral tube, which is placed in a cistern kept constantly full of cold water.

Show a sketch of the still.

Brandy is obtained from wine by distillation. The wine itself consists of water, alcohol, and certain other matters. Alcohol boils and passes off as vapour at about 172° Fah.; water will not boil below 212° Fah.

When the wine, therefore, is heated in the boiler to 172°, the alcohol in it begins to distil over and pass down the spiral tube to be condensed.

The water remains behind, because the temperature is never allowed to reach its boiling point, 212°. Whisky is distilled from malt liquors in the same way; rum from molasses; benzoline from paraffin oil.

IV. Effect of Pressure on the Boiling Point

Place a glass flask, half-filled with water, over the flame, and let it boil till all the air above the water has been expelled,

and its place taken by the steam. While the ebullition is still going on, cork the flask securely, and invert it. The agitation in the water will gradually cease; the boiling will be over.

Take now a sponge of cold water, and squeeze it over the bottom of the flask. The water immediately begins to boil again, although this cooling must have lowered the temperature much below 212°.

Let us see what this means. The steam at first took the place of the air which it had expelled. **It exerted a certain pressure on the surface of the water.**

When the flask was cooled, some of that steam was condensed, and fell in drops of water. There was **less steam then to press upon the surface,** and the boiling began a second time.

At the ordinary pressure of the atmosphere, water does not boil below 212° Fah., but **when that pressure is diminished, water boils at a lower temperature.**

Lead the class to tell from their old lessons that the atmospheric pressure diminishes as we ascend in a balloon, or climb the sides of a mountain.

Tell that on the top of Mont Blanc (15,800 *feet high*) *water boils at about* 180° *Fah.; at Quito* (11,000 *feet*) *the boiling point is about* 194° *Fah.; and at Madrid* (3000 *feet*) *about* 207° *Fah.*

Have it clearly understood that these temperatures cannot be exceeded in any case, because the boiling point is no sooner reached than the water ceases to exist as a liquid, and passes off as steam.

Tell of the effect of this on the process of cooking food in such places.

These lower temperatures are not sufficient to extract all the nourishment and flavour from the food. An egg boiled on Mont Blanc would not coagulate, a potato would remain hard.

In deep mines, on the other hand, the atmospheric pressure is greater, and the boiling point is higher than 212° Fah.

Lesson VII

STEAM AND THE STEAM-ENGINE

I. The Elastic Force of Steam

Introduce the new subject by leading the class to describe some of the effects of heating water to the boiling point.

Water, at the ordinary pressure of the atmosphere, boils at 212° Fah. What do we mean by boiling? Water boils **when it is being converted from the liquid into the gaseous state**—when it passes off as steam.

We know that the water itself at this point—the boiling point—stands at 212° Fah.; but what is the temperature of the steam as it flies off at the spout? That too is 212° Fah. Neither the steam nor the water ever exceeds that temperature.

What, then, is the most remarkable fact about this boiling? The water, after it has reached its boiling point, continues to receive more and more heat, **but it does not become hotter**—the steam does not get hotter.

What becomes of this additional heat? It is used up in actually changing the water into steam.

It is in the steam, although we cannot register its presence by the thermometer.

It is hidden away, so to speak, **in the steam.** We speak of it as **latent heat**; the word "latent" meaning "hidden away."

It is this latent heat **which has overcome the natural force of cohesion in the water,** and driven the molecules or particles so far apart that they form now, not a liquid, but a gas.

If the steam were passed into a cold chamber, it would be robbed of this latent heat, **and the molecules, with nothing to keep them asunder, would rush together by the force of cohesion,** and form a liquid again. The steam would be condensed.

You have all seen the steam rushing from the spout of the kettle, or from the funnel of a locomotive.

Why should it rush in this way? At the moment of the change, so great is the force of this latent heat, that the water expands suddenly to 1700 times its bulk. **That is, a cubic foot of water raised to the boiling point, would make 1700 cubic feet of steam—nearly enough to fill a room 12 feet long, 12 wide, and 12 high.**

It is this **great expansive force of steam**—or, as we sometimes call it, the **elastic force of steam**—which makes it so useful as a mode of motion.

Half-fill a test-tube with water, cork it (but not too tightly), and set it over the flame of the spirit-lamp or Bunsen burner to boil. Presently the cork flies out with a sudden pop, and the steam issues from the mouth.

Either the cork must be forced out, or the sudden expansion will shatter the tube.

The steam will, by its expansive power, force its way out in some direction. There is practically no limit to its expansive force, except the strength of the vessel which holds it.

Give some idea of what this means by telling that sometimes the strongest iron boilers are shattered into pieces by the expansive force of the steam within them.

II. The Principle of the Steam-Engine

Take a glass bulb, having a long neck, the same size throughout. An ordinary long-necked flask will serve the purpose. Fit an air-tight piston into the neck, so that it will move freely up and down. Stand the bulb over the flame of the spirit-lamp or the Bunsen burner.

As the water boils, the expansive force of the steam will send the piston up. The moment this happens, remove the lamp, and cool the bulb quickly in a basin of cold water. Call upon the class to notice that the piston now falls again.

Repeat the heating and cooling to show that the result is always the same. As the water boils, the piston rises; when it is cooled, the piston falls.

Why is this?

Explain that the piston rises because **the expansive force of the steam** *is sufficient to overcome* **the pressure of the air** *on its upper surface.*

But what effect has the cooling process on the steam in the flask? It condenses the steam into drops of water. The water does not occupy so great a space as the steam. Consequently a vacuum is formed; and the pressure of the air from outside re-asserts itself to restore the balance, so forcing the piston down once more.

If we now examine the working of the steam-engine, we shall find that there is a great resemblance in principle to the piston and flask.

The steam-engine consists essentially of a cylinder, fitted with an air-tight piston, which works by the force of the steam up and down, or backwards and forwards, as the case may be. Here we have the principle of the flask and piston.

The difference is that in the steam-engine the up movement and the down are both brought about **directly** by the steam.

Let us find out how this happens.

The water is boiled in a great boiler, and the steam is led by means of a pipe **from the boiler into the cylinder.** But before it can reach the cylinder, it is first admitted into a small sort of box, called **the valve-chest.**

In the opposite side of this valve-chest are **three holes**—two of them communicating respectively with **the upper and lower parts of the cylinder.** The third, which is exactly midway between the two others, is in communication with a chamber known as **the condenser.**

In front of the three apertures is a smooth flat piece of steel capable of moving up and down. **It is known as the slide-valve,** and is just long enough to cover the centre hole and one of the others. **When one of these is closed, the other is always open.**

Lead the class to see that, as there are two apertures leading to the cylinder—one on each side of the piston—if both were open at once the steam would force its way through both; there would be equal pressure on either side of the piston; and of course no movement would take place.

The teacher should make the arrangement clear by a sketch on the black-board.

Imagine now the slide-valve to be in position to cover, and so close, the **lower** of the two apertures leading to the cylinder. **The upper one is open,** and allows the steam to enter the cylinder above the piston. This forces the piston down.

In the meantime the slide-valve has moved up, and is now closing the upper aperture, **leaving the lower one free for the steam to enter.**

There is already steam in the upper part of the cylinder, above the piston.

When therefore the steam enters by the lower aperture, and forces the piston up, that which has done its work above the piston escapes into the **condenser,** and the piston rises because there is no opposition.

The rising of the piston brings the slide-valve down again, the same movements are repeated, and so on perpetually.

This is a description of a very simple and very primitive steam-engine; but whatever work an engine is meant to do, it is all accomplished by the two simple backward and forward movements of the piston in the cylinder, and they are brought about by the expansive power of steam.

Lesson VIII

DISTRIBUTION OF HEAT—RADIATION

I. Radiation of Heat

Stand a boy in front of the fire, and let him tell that he at once experiences a sensation of warmth. The heat, of course, comes from the fire, but how does it reach him?

Does it travel through the air by **conduction?** If so, the air between him and the fire will be very much heated.

Hold a screen of some sort (a small drawing-board) between the boy and the fire, and let him explain that he no longer feels the heat.

Now if the fire sent out its heat through the air by **conduction,** the air itself would be very much heated, and he would still feel the heat, although the screen were before him.

If we stood in the open air exposed to the sun, we should experience exactly the same thing, and immediately the screen was put before us, the sensation of heat would disappear.

Hence then we learn that, although heat does pass **through the air,** from one body to another, it does not travel by **conduction;** nor does it heat to any extent the air through which it passes. **Air is a non-conductor of heat.**

Tell of the heat of the sun in passing towards the earth. It travels through the atmosphere without raising its temperature to any extent.

This is why **the balloonist experiences such severe cold** in the higher regions of the atmosphere, although he is so much nearer the sun.

Lower down at the surface of the earth, the air is more or less warmed **by the heat which is given out** by the warm earth.

But we have not yet seen how the heat does travel through the air.

Take an iron ball, fitted with a chain, and place it in the fire. When it is red hot, remove it, and hang it by the chain in the middle of the room. Stand a number of boys all round it, and lead them to tell that they all feel the sensation of heat from the ball. Others lying on the floor below would feel the same, and so again would others if we could station them above the ball.

Show a big ball of wool, or some such soft material, stuck thickly with pins, all pointing towards its centre.

Imagine that from every point of the red-hot ball **straight lines of heat are sent out through the air,** much in the same way as the pins appear in the surface of the woollen ball.

This is the universal way in which heat travels through the air from one body to another. The screen proves that **the rays travel only in straight lines,** for when it is placed in front of the heated body, it intercepts the rays, and no heat is felt.

We call the straight lines **rays of heat.** We say that the heat travels by **radiation.** We call the body itself which sends out the heat, a **radiator.**

Be careful to explain that this radiation of heat is entirely from the surface; and show why.

Other bodies are warmed by taking in this radiated heat. We say they **absorb** the heat; and we call them **absorbers** of heat.

When we stand in front of the fire to warm ourselves, we are **absorbing** the heat-rays sent out by the fire in our direction. We may stand there too long, or get too close to the fire, and we are glad to move away. Why? We are getting too hot; we should burn ourselves if we remained there.

Explain that **one body radiates heat** *and* **another absorbs it,** *and the double process would go on until both bodies were at the same temperature.*

We could easily prove this by hanging a number of thermometers all round our red-hot ball, and watching it cool.

As the ball cools by radiating its heat, the mercury rises in the tube by absorbing it; and after a time the ball and the thermometers will show the same temperature.

II. Good and Bad Radiators

Now I think we understand what is meant by a **radiator.** It is a heated body which cools by giving off its heat in rays.

Take two "tinned" vessels (ordinary meat-tins will do), the one coated with lampblack on the outside, the other bright inside and out.

Fill them with hot water from the same kettle, and set them aside to cool.

This should be done just before the commencement of the lesson. The attention of the class could be drawn to it casually at the time, and the explanation would follow in due course.

Plunge a thermometer into each.

Now we know that the water that was put into both vessels was of the same temperature. You saw me pour it out of the same kettle. Let us see what the thermometers tell us about it now.

Show that the water in the black-coated vessel has cooled nearly twice as fast as that in the bright one.

Who can explain what this means? **Radiation** has been going on **more rapidly in the blackened vessel** than in the bright one.

The same thing would have happened if, instead of coating the vessel with lampblack, we had covered it with dark-coloured linen, or with brown paper.

What does this teach us? That **dark-coloured bodies** and **rough surfaces** are **the best radiators; white polished surfaces** are **bad radiators.**

III. Good and Bad Absorbers

Place now the blackened vessel and the bright one close in front of the fire. Make the class tell that the fire is **radiating** *heat, which the two vessels are taking in or* **absorbing.** *After a time let one of the class take them up, and tell what he observes as to their temperature.*

The black one is hotter than the bright one. So it would have been if instead of the black coating it had been covered with brown paper or some dark-coloured substance, such as the linen we just used.

What do we learn from this? That **dark-coloured**

bodies and rough surfaces absorb heat more quickly than white polished surfaces like that of the tin.

But we have yet to learn what has become of the heat in the one case, for they both received the same amount from the fire. The black vessel absorbed the rays of heat; the polished one would not absorb them, but sent them back. We say the rays were reflected.

Hence we learn that **the best absorbers are the best radiators**; that **bad absorbers are bad radiators**; that **bad absorbers send back, or reflect, the rays** instead of taking them in.

IV. The Use we make of this Knowledge

1. Metallic vessels, such as kettles, urns, tea and coffee-pots, as well as metallic dish-covers for the table, should always be kept bright. Why? The steam-pipes of an engine should be kept bright. Why?

2. Water will boil much sooner in a kettle covered with soot than in a brightly polished one. Why? The polished fire-irons in front of the fire are often cold when the black fender is very hot. The cooking vessels should therefore be black and rough on the outside, because they absorb heat more rapidly.

3. Light-coloured clothing is the most suitable for summer wear. It absorbs less of the sun's rays than black or dark cloth does.

4. Snow neither absorbs nor radiates much heat. It protects the plants in the ground by preventing the heat from passing away by radiation; while it melts very slowly in a thaw owing to its low absorbing power.

5. Grapes and other fruit ripen best when growing on a black wall. Why?

Lesson IX

HOW HEAT AFFECTS THE ABSORPTION OF VAPOUR BY THE AIR

I. Introduction

Commence the new lesson by leading the children to talk about evaporation; the constant though varying presence of vapour in the air; and its effects.

Suppose we take a towel, weigh it, dip it in water to wet it thoroughly, then wring it out and weigh it again.

What shall we find? It will weigh heavier than at first, because of the water which it now holds.

Suppose again I hang it up in the open air for some time, what will be the result? I shall find it quite dry, and it will weigh exactly what it did when I first weighed it.

The water which it held has disappeared. What has become of it? It has been evaporated, *i.e.* converted into vapour, and **the air has sucked up or absorbed the vapour,** as a sponge sucks up liquids.

Boiling, as we saw in our recent lesson, is essentially evaporation on a rapid and violent scale. The vapour (steam) is formed in masses at a high temperature, and it rises and spreads by reason of its own tremendous expansive force.

The vapour of ordinary evaporation is formed at much lower temperatures, and **rises silently and invisibly, forcing its way,** molecule by molecule, **into the pores** between the molecules of the air itself.

Our former lessons have made us familiar with the fact that the quantity of moisture or vapour in the air is not always the same. It is time now for us to learn the reason why.

II. The warmer the Air the greater its Power of absorbing Moisture

1. **Absorption of moisture by the air.**—Imagine a glass jar, fitted with an air-tight lid, and filled with perfectly dry air, at an ordinary average temperature, 60° Fah. We will place inside the jar a small shallow saucer of water, suspended from a delicate spring balance.

In the absence of actual apparatus, illustrate by a sketch on the black-board.

Now let us see what we have. We have a vessel containing perfectly dry air, and in contact with it there is a small saucer of water. Note what takes place. Evaporation commences immediately, and very rapidly at first.

The air is thirsty and drinks up moisture eagerly. Our delicate scales would soon tell us that the saucer is getting lighter, because **it is being robbed of its water by evaporation.**

In a short time, however, the scales would show that less and less water is leaving the saucer. **Evaporation is slower and slower,** and **at last it ceases altogether.**

The air has finished its drink, it is quite full, it can hold no more. The molecules of vapour have filled up all its pores. **We say the air is saturated,** *i.e.* full of moisture.

Now what is the general effect of heating bodies—solids, liquids, or gases? The heat drives their molecules farther apart, by overcoming the force of cohesion.

If, then, air be heated, and its molecules driven farther apart, it must make **the spaces or pores between the molecules larger.**

Let us suppose, then, that we could suddenly increase the temperature of the jar and its air to 90° Fah.

We should see by the balance again that there would be **a second rapid evaporation from the saucer,** which

would after a time become slower and slower, and at last cease entirely.

Who can tell what all this means? The air at the higher temperature is more porous—it has **greater capacity for absorbing moisture.**

Evaporation commenced again, and went on until all the pores were filled with moisture. It ceased entirely because the air had again become **saturated** at the higher temperature.

Our balance would show us another fact. The amount of water removed by evaporation this time from the saucer would be twice as heavy as at first. That is to say, the increase of 30° Fah. in the temperature has enabled the air **to take up just twice as much moisture** as it could hold at the lower temperature.

2. **Condensation of atmospheric moisture.**—Imagine now the opposite process to be at work. As long as the air in our glass vessel remained at 90° Fah., it would be able to hold all the moisture it had absorbed.

We, however, will suppose that it is suddenly cooled again from 90° Fah. to 60° Fah.

We should see the sides of the vessel become misty, and the interior would be **filled with a dense fog.**

Let us see what this means? The air **is unable,** at the lower temperature, **to hold all the moisture,** and consequently gives up part of it, which **is at once condensed into liquid water again.**

If we could collect all this water, we should find it to be exactly the quantity which was taken up the second time (when the temperature was raised from 60° to 90° Fah.)

If we reduced the temperature of the air still lower, it would give off more and more of its moisture condensed in tiny globules of liquid water.

The children should now be made to tell why wet clothes on a line dry, as a rule, much more rapidly in warm than in cold weather; and always in a dry atmosphere more quickly than in a damp, humid one.

III. Formation of Dew and Hoar-Frost

We have seen that the air at every temperature has its particular **point of saturation.**

Air at the ordinary temperature of about 60° Fah may contain a certain amount of moisture, and yet not be saturated.

But suppose that air becomes cooled, what will happen then? The cooler air cannot hold so much vapour as it did at 60° Fah. The same quantity of moisture is sufficient to quite saturate it, now that it is at a lower temperature.

But suppose it were cooled still further. It was saturated before; its capacity for holding moisture is still less now; **some of the moisture must go.** It does go **It is condensed,** and falls in little round drops of water, which we call **dew.** The temperature at which the air begins to deposit dew is known as the **dew-point.**

Fill a glass tumbler with cold water and stand it on the table in a warm room. The outside of the tumbler will soon become dimmed owing to the deposit on it of little particles of water; these will presently run together into round drops and trickle down the sides of the glass.

Tell that the drops of water came, not from the tumbler, but from the moisture in the air of the room.

The air was able, at its particular temperature, to hold a certain quantity of moisture.

The cold glass reduced the temperature of the air around, first **to its point of saturation,** and afterwards **to its dew-point;** and then the drops of dew began to form on the cold glass.

Dew is always formed in this way—not in the air, like fog and cloud, but **on the cold surface of solid bodies.** There is always some solid body colder than the dew-point of the air around.

The air comes into contact with this colder body, and is robbed of some of its heat. The loss of heat compels it to give up some of its vapour, and this is deposited as drops of dew on the surface of the cold body itself.

All day long the earth and all the objects on its surface **are absorbing more heat** from the sun than they give out by **radiation.** When night comes on, the absorbing process is over, and the radiation only is going on. Consequently the surface of the earth and of most solid bodies at night is continually **losing heat,** and is, as a rule, **colder than the air near it.**

Hence the formation of dew when this warm air comes into contact with it.

When the temperature of the earth and the solid bodies on its surface sinks below 32° Fah., the moisture is deposited in the form of tiny particles of ice. **We call it then hoar-frost.**

Dew is usually formed on a fine, clear, still night succeeding a warm day. Very little dew is formed on a cloudy night. The clouds act like a curtain, and prevent the radiation of heat from the earth.

Dew is formed abundantly on **grass and foliage** generally, on **trees** and on **wooden palings**; but very little is formed on the gravel paths or the stone pavements. Gravel and stone are bad absorbers and bad radiators of heat.

Lesson X

HEAT, THE CAUSE OF MOTION IN THE AIR

I. Air Currents and how formed

Take a large glass jar, or a bottle with a very wide mouth. Divide it into two partitions by fitting into it a piece of stout card-board from the neck to within an inch or so of the bottom. Lower into it on one side of the partition a piece of lighted candle. Hold over it some smouldering brown paper, and let the class note the result. The smoke from the smouldering paper is seen to pass down one side of the glass, then under the partition, and up the other side, in which the candle is burning.

Lead the class to tell the reason of this.

The heat of the burning candle raises the temperature of the air all round it, and causes it to expand. It is therefore lighter than it was—lighter than the rest of the air near it—and **it consequently ascends.**

But as the warm, light air passes out at the top of one side, **the cold air from the other side rushes under the partition** to take its place, and so prevent a vacuum.

We could not see the moving current of air in the usual way, so we put the smoking paper over the mouth of the glass, and that showed the direction of the movement.

Explain that the heat from the gas-burner or a lamp in a room acts in much the same way. It raises the temperature of the air around, and this heated air ascends towards the ceiling, the colder air constantly moving in from all sides to take its place and force it upwards.

The hottest air in the room is always near the ceiling; the coldest near the floor.

This light, hot air in the upper part of the room **will do its best to escape,** and float away higher and higher outside, if it can find a crack or an opening anywhere.

When the room is warm, pull the window-sash down about half an inch from the top, and hold a lighted candle near the opening. **The flame will pass outwards through the crack.**

Now open the door a little way, or hold the candle-flame near the crack at the bottom. **The flame will be blown into the room.**

Make the children explain the reason in each case.

The fire in the grate acts in the same way, although the heated air passes up the chimney with the smoke, and not into the room. There is, however, **a constant movement of cooler air** through the room **towards the fire,** to take the place of that which has floated away up the chimney.

II. Ventilation

The burning of the candle, the gas, or the oil in the lamp affects the air of the room in another way besides heating it, and thus causing it to expand and become lighter than it was at first.

Who can tell what I mean? The burning in each case produces a poisonous gas, carbonic acid, which floats away into the air.

That is to say, the air of the room, which was pure at first, becomes in time loaded with carbonic acid gas from the burning.

I think too you can tell of another way by which the air becomes loaded with carbonic acid. We and all other animals are constantly sending out carbonic acid into the air by breathing.

We called this carbonic acid **a poisonous gas.** Why? Because we could not breathe it, even in a small quantity, without making ourselves ill; and in a larger quantity it would mean death.

Imagine a man shut up for twenty-four hours in a room 7 feet square and 8 feet high. At the end of that time every particle of air in the room would have passed through his lungs, he would have robbed the air of about one-twentieth of its oxygen, and breathed out into it an equal amount of carbonic acid.

Such air would be quite unfit to breathe. But as long as the man lives he must continue to breathe; and thus at every breath he would now be inhaling large quantities of this poisonous gas.

Picture two or three people, instead of one, in such a room. What would be the result? Tell the story of the Black Hole of Calcutta.

In our school-rooms, public halls, and all buildings where many persons meet, as well as in our living and sleeping rooms at home, every care should be taken to see that there is a way of escape for the heated, vitiated air,

and a free communication with the fresh air on the outside.

This is what we mean by **ventilation.** There are many artificial contrivances for admitting the fresh air and driving out the bad. Most of them are constructed somewhat on the principle of the fan; they set the air in motion just as a fan does when we move it to and fro.

The word **ventilation** itself comes from a Latin word, which actually describes the waving movement of a fan through the air.

III. A FEW PRACTICAL HINTS

We cannot all have costly contrivances for ventilating our rooms, but we can all make use of a few simple, practical hints.

1. The top sash of the bedroom window should be kept down an inch or so day and night, for the escape of the foul air. Or a row of holes may be bored in the upper part of the frame with a gimlet. This will answer almost as well.

But how about letting in fresh air to take the place of the bad air which escapes in this way? **We need not trouble about this.** The bad, heated air will be sure to rush away if we leave a means of escape for it in the upper part of the room; and the pure air will force itself in through every crack and crevice, through the keyhole, under the door, to take its place as quickly as it passes off.

As the air which enters the room in this way has to pass through the house, it is important to keep the house and all things round it clean, and free from bad smells, or we shall be admitting bad air into the room to begin with.

This applies to all work-rooms and class-rooms as well as to sleeping-rooms, especially when gas is burned. The only thing to be avoided is the causing of draughts. Draughts create mischief.

2. The best ventilator for a room is a fire.

Let the class explain why?

If a number of persons sit in a room without a fire, the air soon becomes stuffy and foul; but if a fire is burning in the grate, it will help very much to keep the room ventilated. Why?

3. A simple way to rapidly purify a close, foul room is to open both the top and bottom sashes at once. Why?

The contrivances, whatever they may be, for ventilating the class-rooms of the school should next be explained. It should be clearly shown that these accomplish what is required. They admit the fresh air, and carry off the bad, without causing a draught.

A few of the simple mechanical contrivances in use may also now be described.

Lesson XI

WINDS AND CURRENTS

I. Winds

Imagine a great bonfire burning in the middle of a field on a calm, quiet evening. Immediately the flames begin to ascend the persons standing round will feel currents of cold air pushing in from every quarter towards the fire.

Imagine a number of flaming torches set up all round the field. The tongues of flame would in every case stretch out towards the fire in the middle. Long, thin, paper streamers would point in the same direction. Why? Make the class tell.

This movement of the air as the result of heat from the bonfire is an illustration of the way in which winds are formed. These currents of air setting in on all sides towards the fire are actually winds on a small scale.

Wherever winds occur, something similar to this has been going on. The air in some spot has been greatly heated, and of course expanded, and thus made light, and it ascends. Colder, heavier air then rushes in from all

sides to fill up the vacuum. The rushing air forms the wind.

Land and sea breezes are the simplest illustration of the formation of winds.

Lead the class to tell the meaning of the terms **absorption and radiation of heat.** *Good absorbers are good radiators, and* vice versa.

The land is a better absorber and therefore a better radiator of heat than the sea.

The sun shines all day with equal power on the land and on the adjoining sea; but **the land takes in more heat than the sea.** It radiates it into the air, however, as readily as it receives it; and thus the air above the land becomes hotter than that over the sea.

The hot air from the land rises, and the colder, heavier **air from the sea rushes in** to take its place. Thus all day long we have a breeze blowing from the sea to the land.

Now when the sun goes down, the source of heat is gone. The land is no longer absorbing heat. Throughout the night, however, the land continues to give up, by radiation, the heat it has taken in during the day. It soon becomes cold therefore—**colder than the sea,** which, although it has absorbed slowly, has also radiated slowly. The air therefore above the water is warmer in comparison than that over the land.

During the night the warmer air above the water rises, and the colder **air from the adjoining land rushes onwards** to take its place. This gives a land breeze, which lasts till the sun next morning begins to assert its power, and then the breeze from the sea sets in once more.

Lead the class to think of the tropical regions of the globe. Tell of the powerful effect of the sun in heating the air in those regions. The heated air rises, and, naturally, movements of colder air from the temperate and polar regions north and south set in towards the equator.

The directions of these winds are modified from various causes, but their origin is always the same.

Tell how the ascending air forms an upper current, and flows north and south towards the poles. It gets colder and colder as it proceeds, and as it cools it descends.

Illustrate the whole phenomena by reference to the boiling of water in the flask.

II. Ocean Currents

We have frequently spoken of the effect of the sun in heating and evaporating water. In what part of the world should we expect to find this going on to the greatest extent? In the great oceans of the torrid zone.

Lead the children to think of the immense quantities of water daily evaporated from the sea in this way. This water is actually removed from the ocean.

If I take a cupful of water out of a large vessel, you know that I cannot leave a hollow. The water from all sides rushes in to fill up the space or vacuum.

Somewhat in a similar way the removal of immense masses of water from the ocean by evaporation in these torrid regions tends to destroy the balance of pressure, and to cause a vacuum. To fill up the vacuum there is **a rush of colder, heavier water from the polar seas.**

Such a stream of water flowing through the ocean is a current. **The currents are actual rivers flowing through the ocean.**

These ocean rivers from the polar regions consist of dense, cold water. Where should we expect to find them? They flow along the bed or bottom of the sea.

But the sun does more than actually evaporate the water of the ocean. It also heats to a considerable extent the whole of the surface-water.

This surface-water is therefore warmer and lighter than that which flows in from the poles.

Thus the rushing in of the colder, heavier water below, **forces the lighter surface-water onward,** and compels it to flow towards the poles to restore the balance.

Take the globe and illustrate this by following the great

equatorial current, and its final development into the Gulf Stream.

Describe this important current and its influence on the climate of western Europe. It is veritably a warm river rushing through the Atlantic at the rate of from 50 *to* 60 *miles a day.*

Lesson XII

SPECIFIC HEAT

I. Meaning of the Term

What would happen if I plunged the red-hot poker into a vessel of ordinary cold water? The heat from the poker would be given up to the water, and would raise its temperature; the poker itself would be cooled by contact with the water.

Let this be done, to prove that it is so.

Now we will take two balls, one of iron, the other of lead, and place them in boiling water. Let them remain in the water till the thermometer shows that they are themselves heated to 212° *Fah.*

Then remove them and plunge them into equal quantities of cold water from the tap.

What will be the effect of the heated metal balls on the water? They will heat the water itself. Let us see. The thermometer will at once tell us of any change of temperature in the water.

Show that, while the iron and the lead both heat the water, that in which the iron was placed **is much hotter than that which holds the lead.**

Now if the iron has made the water in the one basin hotter than the lead has made that in the other, it is clear that **the iron has given out more heat than the lead.**

But whence did both get their heat? From the same vessel of boiling water.

What does this show, then? That iron is able to take in and hold more heat than lead.

The result would be very similar if we substituted any other substances for the iron and the lead. We should find that **some substances have a greater capacity for holding heat than others.**

This is exactly what we mean when we speak of the **specific heat of different bodies.**

Take two equal quantities of water, one at a temperature of 212°, *the other at* 32°, *and mix them well together. Test the mixture with the thermometer, and show that the temperature now is* 122°.

Explain how this comes about. The difference between 212° *and* 32° *is* 180°. *The hot water gives up, and the cold receives, exactly half this,* i.e. 90°. *Thus* $212° - 90° = 122°$; $32° + 90° = 122°$.

Tell that it would be exactly the same if we mixed oil with oil, or mercury with mercury. The resulting temperature is always midway between the two.

The quantity of heat which the hot liquid gives out in cooling through a certain number of degrees is just what is required to raise the temperature of the cool liquid through as many degrees.

But we will now take equal quantities of mercury and water, the mercury being at a temperature of 212°, *the water at* 32°. *On mixing these, and testing with the thermometer, we shall find the new temperature to be a little below* 38°.

That is, the water will have gained only about 6° in temperature. But the mercury has been lowered from 212° to the same temperature, 38°.

That is to say, the mercury has lost $212° - 38° = 174°$, and all this heat has been absorbed by the water.

If, on the other hand, we took water at 212°, and mercury at 32°, and mixed them in equal quantities, we should find the resulting temperature of the mixture to be about 206°. The water would part with only about 6° of its heat, but this would be sufficient to raise the temperature of the mercury from 32° to 206°; *i.e.* $32° + 174° = 206°$.

So that the quantity of heat which is sufficient **to raise the temperature of mercury 174° will raise an equal amount of water through only 6°.**

This shows, by another method, that water has a greater capacity for taking up and holding heat than mercury. We say that **the specific heat of water is higher than that of mercury.**

II. Some Bodies heat and cool more rapidly than Others

Take two small test-tubes, one containing water, the other an equal quantity of mercury at the same temperature. Immerse both in boiling water, with a small thermometer in each to indicate their rise in temperature. Let the class note what follows.

The mercury in the one tube will be seen to reach 212° Fah. in about half the time that the water in the other tube takes.

Now remove them from the heat, while both stand at 212° *Fah., and leave them to cool.* **The mercury will cool twice as rapidly through the same number of degrees as the water does.**

Hence we see that water takes twice as long as mercury to reach a certain temperature; and is twice as long in cooling.

The same thing would happen with the lead and iron balls. The lead cannot take up so much heat as the iron. It would therefore reach the temperature of the boiling water in much less time than the iron. As it cannot hold so much heat as the iron, it has less to part with when it cools. Hence it cools more rapidly than iron.

We might expose a variety of substances to the same source of heat—say by placing them in front of the same fire—and we should find that **some would rise in temperature more slowly than others.**

If we removed them in their heated state, at the same

moment, into a cold room, those which had grown hot slowly would also cool slowly, and *vice versa;* because those which have a greater capacity for holding heat than others have more to take up in heating, and more to part with in cooling, and must therefore take longer.

III. The Effect of these Differences in Specific Heat

1. Water, as we have seen, has a high specific heat. That is to say, in rising through any number of degrees in temperature, it requires to take in an immense quantity of heat, and hence **it takes longer to get hot and longer to cool than other bodies.**

Lead the class to think of the oceans, rivers, and lakes all over the world, with their countless multitudes of living inhabitants.

It is this high specific heat of water which makes rapid elevation or depression of temperature in the ocean impossible.

Picture an ocean of mercury under the rays of a tropical sun. Even if it were otherwise habitable, the creatures in it could never live through such sudden changes in temperature as would certainly take place. Such a liquid would be quite uninhabitable.

During the cold season of the year, too, the sea and all great bodies of water cool. But in cooling they have a great quantity of heat to give out for every degree they lose in temperature. Hence they cool very slowly, and while cooling the heat which they give out tends to equalise the temperature of the adjoining land.

2. Mercury has a low specific heat. A comparatively small quantity of heat is sufficient to raise its temperature through any number of degrees. Hence it rises and falls in temperature very rapidly. It is this which makes mercury so peculiarly useful for filling thermometers.

DOMESTIC ECONOMY—FOOD

(GIRLS ONLY)

Lesson XIII

WHY WE EAT

I. Introduction

Take an ordinary hen's egg and break it in a cup before the class. Point out the **germ** *or* **embryo** *floating in the yolk.*

If this egg had been hatched by keeping it warm for about three weeks, the little embryo would have become an actual chicken; it would have had strength enough to break the shell and set itself free, and would then have been able to run about and seek its own living.

Now, how does it happen that a little speck like that can grow into a chicken? Let us find out.

Remove the germ. This is the embryo, future chicken.

What then is all this other matter? All that we see now in the cup is simply a store of food laid up within the egg-shell for the tiny germ to feed upon.

Day by day the little thing absorbs more and more of this food-store into itself, and **with it builds up its own body.**

Day by day, during those three weeks, the little body is getting bigger and bigger, and **the store of food in the shell is growing smaller and smaller.**

At the end of the three weeks the supply is exhausted. What is to happen now? The little creature is now fully formed and able to look after itself. It commences to do this by pecking with its beak all round the inside of the shell until it breaks it, and then out it comes.

If we were to take it up immediately in our hands and examine it, we should find its little body to consist of flesh and bones, with feathers already growing on the skin—eyes, bill, feet, everything perfectly formed. Its body would feel warm, and it would show, by its struggles to get free, that it had a certain amount of strength.

Now all these things—the flesh, bones, and blood of its body, with the clothing of feathers, as well as the warmth which you feel and the strength which it shows—**all come from the food which it has taken while in the egg-shell.**

The little chicken has to grow into a large fowl. How is this brought about? By the food which it eats after it is able to run and seek its own living.

Follow up the same idea with nature's other food—milk.

The little kitten, the little rabbit, the little baby grow and become strong by the food—milk—which the mother supplies until they are able to eat other food.

II. Kinds of Food

Nature, we see, in each of these two foods—the egg of the bird and the milk of the mammal—has supplied everything that is necessary for the life and growth of the little creature. Let us try and find out what these different things are.

Proteids or flesh-formers.—The little chicken leaves its shell with every part of its body perfectly formed, and all these tissues—flesh, bones, blood, feathers—it makes from the food it finds in the shell.

(*a*) **Flesh.**—Think of a piece of lean flesh—a joint of beef in the butcher's shop. It looks very solid now, but if we were to place it over a fire, we should see it begin to give off vapour, and it would continue to do so until it had lost 77 per cent of its weight. That is, a piece of beef weighing 100 lbs. would weigh only 23 lbs. when it had been perfectly dried. The vapour has taken, as you

know, nothing with it, hence we learn that 77 out of the 100 lbs. consisted of water.

The 23 lbs. of solid matter left behind consists mainly of a substance commonly called **fibrin**, but more strictly known in the scientific world as **myosin.** It is the chief constituent of all flesh.

(*b*) **Bones.**—*Show a bone that has been allowed to stand for some days in dilute muriatic acid (spirits of salt). Let the class examine it, and see that, while it retains its form, it has lost the hard, firm, rigid nature usual in bone, and has become flexible.*

Cut it with a knife. Tell that the bone, as it now appears, consists of a substance known as **ossein,** *which when boiled yields a sort of glue which we call* **gelatine.** *The same substance helps also to form the skin, nails, hair, and feathers.*

(*c*) **Blood.**—A quantity of blood, dried over the fire in the same way as we dried the flesh, would show a loss of 76 parts of water out of every 100 parts, thus leaving about 24 parts of solid matter. The solid matter consists chiefly of the two substances of which the flesh and the bones are formed—**myosin** and **ossein.**

These substances, which form **the chief solid constituents** of the tissues of the body, are called **proteids, tissue-formers,** or **flesh-formers.**

Lesson XIV

FOOD—WHY WE EAT

I. Recapitulation

Lead the class to talk about the provision which nature makes for feeding the young bird and the infant mammal.

All the food which the embryo chick requires for its growth and support is stored in the egg; all the food which is necessary for the infant mammal is present in the milk which the mother supplies.

Lead them to tell the nature of a proteid.

These are the materials which build up the solid substance of the body.

Impress upon them again that the particular proteid for building up bone-substance will not make muscle or flesh, and vice versa.

Let them explain carefully the experiment with the bone in the muriatic acid, and see that they understand clearly what has taken place. The acid has dissolved part of the constituents of the bone, but cannot dissolve the tissue-forming gelatinous substance.

Explain that the blood has to build up and nourish the bony as well as the fleshy structures of the body. Hence in the blood we find both the gelatinous substance and the fibrin.

II. Tissue-Formers

Break an egg in a cup, as in the last lesson.

Call attention to the clear, glairy fluid in the cup. Pour it into a basin of boiling water. Show what has taken place.

It is solid, white, and opaque now. We call it "white of egg." Its scientific name is albumen (*albus* = white). This **albumen** is a **proteid** or **tissue-former.** It was with this that the little chicken built up its tissues while in the egg-shell.

Curdle a little milk and call attention to the white, opaque, solid substance, **curds.** *Tell that its proper name is* **casein.**

It is the **proteid** or **tissue-forming** element in milk, and it is with this substance that the young, sucking mammal builds up its tissues.

The food which every animal afterwards seeks for itself must contain tissue-forming matter of some kind, because its body has to grow, and its tissues have to be constantly renewed. Why?

1. **Heat-giving foods.**—(*a*) **Fat.**—The little chicken's body felt warm; our own bodies are warm, and must be kept warm.

In the yolk of the egg was stored up a quantity of oily, fatty matter. It was this which gave the heat. We shall find out how in a later lesson.

Show a little cream. Let the class tell whence it comes, and its chief use in butter-making.

This oily, fatty cream is the heat-giving element in the milk of the mammal.

But why is heat necessary to our bodies? **It is the heat produced by the food that supplies all the vital force and power and energy of both body and mind.**

Lead the class to think of a steam-engine ready to work, but powerless to move a wheel till force is put into it.

Whence comes this force? From the fuel which is burned in its furnace.

So in the body, **the food is the fuel,** and without fuel to burn the fire would go out, the body would become cold and powerless; it would die.

Fat of all kinds is a heat-giving food.

(*b*) **Sugar.**—*Burn some sugar in an iron spoon; show that it is readily combustible and gives out great heat.*

When taken as food sugar is a source of heat to the body. **It is a heat-giving food.**

We obtain sugar from the sugar-cane, beet-root, and the sugar-maple tree, but sugar also exists in the juices of fruits and in some vegetables.

(*c*) **Starch.**—*Refer to some of the earlier lessons, and lead the class to tell all they can of* **starch**; *its existence in the corn grains, in potatoes, in peas, beans, arrowroot, etc.; its conversion into sugar by the saliva, in the act of mastication.*

How can we obtain the starch from a handful of flour?

Starch is valuable as a food simply **because it can be changed into sugar,** which in the body becomes a heat-giving food.

2. **Bone-making food.**—*Take another bone, similar to the one standing in the acid, and burn it for some time in a very bright red fire. When cold, have it examined by the class. It retains the form of the original bone, but it is now very brittle*

and will crumble up. Break it with the fingers. Tell what has happened.

The whole of the glue-like substance has been burned up in the fire, and nothing remains but this earthy mineral matter.

In the experiment with the other bone, the acid dissolved all the mineral matter and left only the glue-like, tissue-forming substance.

In the body the soft gristly parts are made into bone by the help of mineral matters. We therefore call this earthy mineral matter **bone-forming food.**

Tell that by burning a carrot, a cabbage, or a potato it is possible to find these mineral matters. The rest of the vegetables will burn away. The earthy parts will not burn, they remain as an ash.

The water we drink contains **dissolved minerals**; **salt is a mineral**; all our **fresh vegetables contain minerals.**

Mineral matter was present in the egg and in the milk, ready to do its bone-forming work.

Lesson XV

ANIMAL FOOD

I. Introduction

Commence by leading the class to talk about the three kinds of food-stuffs mentioned in the last lesson—tissue-formers, heat-givers, bone-makers.

Our daily diet should contain all these three in some form or other, but not in equal quantities. We require daily just sufficient tissue-forming and bone-making materials to renew the waste which is going on, and just enough fuel to create the necessary amount of heat. It is found that the body needs nearly **four times as much**

heat-giving as tissue-forming food, and not more than a quarter of that amount of bone-making or mineral food.

If we take more or less than these proportions, the body suffers in some way or other.

These food materials, as we have seen, may be obtained from both the animal and the vegetable world. We shall in this lesson confine ourselves to the first of these.

II. The Flesh of Animals

Let the class enumerate the various animals whose flesh we use as food.

The sheep, ox, and pig give us mutton, lamb, beef, veal, pork, and bacon. Poultry (fowls, ducks, geese, turkeys, pigeons) supply nourishing food of another kind. The flesh of the deer gives us venison; and certain other wild animals such as hares, rabbits, partridges, pheasants, grouse, and woodcock are called game.

The special value of flesh-food is due to its close similarity to the fleshy parts of our own bodies.

The muscular or lean fleshy parts of the meat contain the proteid substance **myosin,** the very identical material of which our own bodies are made, and therefore specially well fitted for building up our own tissues.

Mixed with the lean of all meat, however, there is always more or less fat—the amount varying in the different animals and according to the manner of feeding. This fat is, as we have seen, an important heat-giving food. Taken into the body, it does not build up the tissues, but it burns, and **in burning creates the heat** which the body requires.

Flesh-meat varies in usefulness in proportion to its digestibility. Mutton, venison, poultry, and game are **easily digestible**; beef, though it contains much nourishment, is **not so easily digested**; pork and veal are **less digestible than either.**

The quality of the meat, both for flavour and digestibility, may be readily detected by the juices in the lean,

which give a delicate colour and softness to the flesh. **This fact should never be forgotten when one is choosing a joint of meat at the butcher's.**

The final value of the meat, both as regards economy and also its excellence of flavour, depends largely upon the cook.

III. Milk, Butter, and Cheese

Our last leſson showed us that milk too contains a **heat-giving** and a **flesh-forming** element. What did we call the heat-giving material? Cream.

How was it obtained from the milk? The milk was allowed to stand quietly for a time, when the cream, which consists of tiny globules or bladders of fatty or oily matter, rose to the surface, because they were lighter than the other parts.

The purpose of churning is to burst the delicate skin which encloses the little globules; the oily, fatty matter then forms into lumps of butter.

When the cream has been removed from the surface, the skim-milk left behind in the pan may be still further separated into two distinct parts. In the dairy this is done by pouring in **rennet,** but vinegar or any acid will separate them. In fact they separate themselves when the milk turns sour.

Make the class describe the white solid curd, and give its name—**casein.**

This we noticed in the last lesson as the flesh-forming principle of milk. In the dairy it is collected and made into cheese by squeezing out the water and drying and pressing it into moulds.

Cheese may be made either of new or skim-milk. If made of new milk, it contains a large amount of the fatty element, butter, as well as the essential principle, **casein.** This adds to its flavour, and thus to its market-price, but does not make it more valuable as a flesh-forming food.

Cheese made from skim-milk contains as much casein as that made from new.

Cheese, taken in large quantities, is neither a good nor an economical article of food. Few persons are able to digest a large piece of cheese at one time, although it is said to assist the digestion of other food if taken in small quantities—certainly not exceeding an ounce at a meal.

But we have the other element of the milk to consider next. This is a thin, watery fluid, called **whey.** Dissolved in the water are certain **mineral salts,** as well as from 3 to 5 per cent of **milk-sugar.**

Remind the class again of the essential purpose of milk as one of nature's foods, and lead them to see the part which these constituents are designed to perform in nourishing the young animal.

IV. Eggs

Lead the class to describe the constituent parts of an egg, as far as they were treated of in the last lesson.

What becomes of the clear, sticky, colourless portion when it is boiled? What name do we give it? Albumen.

This **albumen** is an important constituent of the yolk, as well as of the rest of the egg—20 per cent of the yolk itself consists of albumen. What else did we find in the egg? A yellow, fatty oil. This oil forms 30 per cent of the yolk of the egg.

Make the class tell the distinctive parts to be performed by the albumen and the oil in feeding the growing chick.

As an article of food, eggs should be but lightly cooked. The albumen in its raw state is easily digestible, but when boiled it becomes hard and more or less indigestible.

V. Fish

Many kinds of fish are used as food—the commonest are the herring, cod, mackerel, whiting, haddock, plaice, sole, turbot, and salmon.

The solid constituents of the body of a fish contain the

same substances—**fibrin** and **fat**—as make up the bodies of other animals.

Fish, however, are less nutritive as food, because their bodies contain, weight for weight, much more water than the flesh of other animals does.

The cheaper varieties of fish contain more nutritive matter in the form of fibrin than some of the more expensive. Thus herrings contain a very large amount of fibrin; salmon, much less in proportion.

Some fish, such as the herring, pilchard, eel, and salmon, contain a large quantity of oil or fat; others, such as the sole, whiting, haddock, plaice, and cod, have very little oil.

Lesson XVI

VEGETABLE FOODS

I. Sources

We use many varieties of vegetable substances as food. The principal are the corn grains—wheat, oats, barley, rice, and maize; the preparations known as sago, arrowroot, and tapioca; the seeds of beans and peas; fresh vegetables, such as are sold by the greengrocer; fruits; and sugar in various forms.

II. Farinaceous Foods—the Corn Grains

1. **Wheat.**—*Show a few ears of wheat and a picture of the growing plant. Let one of the class come to the front and wash the starch out of a muslin bag of wheaten flour, as they have seen it done in the earlier lessons.*

What have we left behind in the bag? A white, sticky substance resembling bird-lime.

Show it. We call it **gluten.**

This gluten is of very much the same nature as the

albumen, myosin, gelatine, and **casein** of animal food. It is **a tissue-forming** substance.

What have we in the water? Starch.

Cut open a few grains of wheat and hand them round for examination. Show that the grain consists of a white central substance enclosed within an outer covering or skin.

The white inner substance is the **starch**; it is the outer coating which contains the flesh-forming principle—**gluten.**

The miller, after grinding the grain, passes the meal through a series of sieves. The first sieve separates the larger particles from the rest. These are portions of this very outside skin, and are sold as **bran.** The second sifting separates some finer portions of the same skin, which are known as **pollard.**

The brown meal which now remains is really the best and most nourishing of all, for it contains all the **gluten.**

Many people, however, prefer white bread; and hence the meal is sifted again and again, the result being that much of the **gluten** is separated, and the flour is white, **only because it consists very largely of starch.**

Pure wheaten flour contains about 12 per cent of gluten, 60 per cent of starch, and 14 per cent of water. The remainder is made up of sugar, fat, and mineral matter.

The different qualities sold are known as "brown meal," "households," "fine households," and "best." This last makes the whitest bread, but is it really the best?

2. **Oats.**—*Show some stalks of common oats, and compare them with the wheat-stalks.*

Wheaten flour is almost universally used in England, but in Scotland it gives place to **oatmeal,** that is, the meal or flour of ground oats.

Oatmeal is even richer than wheaten flour in **gluten,** for it contains no less than 18 per cent of this flesh-forming substance.

Oatmeal will not make up into light spongy bread, such as we make with wheaten flour. Hence the Scotch people eat it in the form of **porridge and oatcake,**

and as such it forms their principal food; and a very valuable food it is.

In England, almost the only use we make of oatmeal is for gruel in the sick-room.

3. **Barley.**—*Show some ears of barley side by side with the other two. Compare them.*

Barley-meal, although largely used in feeding cattle and pigs, is not made into bread in these islands, except in a few places in the north, where it is mixed with equal quantities of wheaten flour, and eaten in the form of cakes called **bannocks.**

We usually see it as **pearl barley** and **Scotch barley**; and in this form it is used for making soups and broths.

Nearly all the barley that is grown in England is used in the preparation of **malt** for beer.

4. **Maize.**—*Show a specimen of the "cob" or head of maize, a few of the ripened grains, and a picture of the growing plant. We call this maize or Indian corn.*

Maize is not grown in England—our summers are not long enough to ripen the grain. It is grown largely in many parts of the world, and is an important article of food.

In America, the people not only grind the ripened grains into flour, and use it as we do wheaten flour; but they cut the green "cob" before it is ripe and boil it for the table. In this state it makes a most delicious vegetable.

In using maize-flour for bread it is customary to mix it with an equal quantity of wheaten flour.

The Americans use much of their maize-flour for porridge, eating it with milk and sugar. Its common name is **stirabout.**

Nearly all the Indian corn that comes to this country is in the form of **corn-flour.** It consists entirely of the starchy principle of the grain, and is used for making milk-puddings, blanc-manges, etc.

Refer to one of the early lessons on starch, and lead the class to describe the mode of its preparation.

Maize contains more gluten and more fat than wheaten flour, and thus it is a most wholesome and economical food; and in those countries where it is grown, it produces a very profitable crop, for the produce of a single seed is greater than that of any of the corn grains.

Show the "cob" again, and explain that this is only a single ear.

5. **Rice.**—*Show a picture of the rice plant, a few specimens of the grain in various stages of its preparation, and a little rice-flour.*

Refer to the earlier lessons, and help the class to tell where and how it is cultivated.

Rice forms the staple food of the people of the East. It is to them what bread is to us.

It contains a very small amount of flesh-forming matter—not more than 6 per cent, *i.e.* much less than any of the other corn grains. In fact, it consists very largely of starch. Nearly 75 per cent of the grain is starch.

It is therefore not of much value as food, unless used with some other food rich in flesh-forming and fatty elements.

We use rice both whole and in the form of meal, but we always use it with such other things as eggs and milk, or in soups. Why?

6. **Sago, arrowroot, and tapioca.**—*Make the class tell, by referring to the earlier lessons, the nature, growth, and preparation of each of these.*

Show, if possible, pictures of the plants, and some specimens of the articles themselves.

Our business here is merely to arrange them in our list of starch-foods. They each consist almost entirely of starch; **they contain no flesh-formers.** Considered as food, they have little value unless used with some tissue-forming and fatty substances; for they are quite incapable of supporting life alone.

All these starch-foods—the corn grains as well as sago, arrowroot, and tapioca—are known as **farinaceous foods,** because they all contain **farina,** *i.e.* fine meal.

Lesson XVII

VEGETABLE FOODS

I. INTRODUCTION

COMMENCE by leading the class to recapitulate rapidly the subject of the last lesson.

In what respect do all the vegetable foods we then considered resemble each other? They all consist very largely of **starch.**

What name do we give them because they all yield meal? We call them **farinaceous foods,** from "farina" the Latin name for flour.

Some of them contain, in addition to the starch, a flesh-forming substance; what do we call it? **Gluten.**

In which of these farinaceous foods is gluten found? In the corn grains.

Which are those that consist of pure starch alone? Sago, arrowroot, and tapioca.

II. LEGUMINOUS FOOD

Show some peas and a few different kinds of beans, such as the broad or Windsor, scarlet-runner, and French varieties. If the season of the year render it possible, provide also green specimens in pods.

Let the class examine the seeds, and remind them by referring to their lessons on plant-life that in these, as in all vegetable matter, the basis of the substance is starch.

The young peas always taste sweet. The fact is, they contain starch, which is readily converted into sugar by the saliva.

If we were to hold some pea-meal in our mouths for a short time, we should find that it would gradually assume

a sweet taste. It contains starch, and the saliva changes the starch into sugar.

Peas and beans of all kinds, however, are less valuable for the starch which they contain than for some other substance.

Indeed, they contain less starch than any of the farinaceous foods of last lesson.

They all contain nearly a quarter of their weight (from 23 to 25 per cent) of a valuable tissue-forming substance known as **legumin**. That is, they contain much more tissue-forming substance than wheaten-flour, oatmeal, or butcher's meat.

This legumin, when separated out from the starch and other matters of the seeds, is found to be very similar in character to the **casein** of cheese. In fact, the Chinese actually make a kind of cheese from the legumin of peas.

Beans and peas, in the dried state, are not eaten very largely, in spite of their valuable flesh-former, **legumin**, for they are somewhat difficult to digest. Both, however, in their growing state, as green vegetables, are favourites with most people, and are regarded generally as luxuries of the table.

We use the green pods as well as the seeds of the scarlet-runner and French bean; but the seeds only of the broad bean and the pea are cooked.

When used in the dried state, the only things necessary to make peas and beans of all sorts excellent food are good soaking in cold water and careful cooking.

A good plan is to soak them in cold water for one day, and then let them stand for a couple of days out of the water, but in their wet state. Under these conditions, the seeds will commence to grow, and as soon as this happens the softened starch will be converted into sugar. They then require careful boiling for two or three hours.

This treatment will render them perfectly digestible for all except the most delicate persons.

It is in the highest degree important to remember that, provided they can be rendered easy of digestion, peas and

beans are a most economical food, because they contain such a large proportion of the flesh-forming matter **legumin.**

One of the most valuable of these **leguminous foods** in the dried state is the **haricot bean.** This is really the dried seed of a small white variety of the French bean.

III. Fresh Vegetables

In this class we include tubers such as the potato; fleshy roots such as the turnip, carrot, parsnip, and radish; as well as green vegetables like the cabbage, lettuce, spinach, cauliflower, water-cress, onion.

These, like all vegetable food, contain both flesh-forming and heat-giving elements in various proportions.

The potato, although it contains little or no nutriment for tissue-forming, is a very valuable heat-giving food. **Nearly all its solid portion consists of starch.**

Carrots, turnips, parsnips, cabbages, cauliflowers, and onions are very nutritious, both as tissue-formers and heat-givers.

If I were to set one of these fresh vegetables—a potato, a turnip, a cabbage, or a cauliflower—over the fire or in an oven, what should I notice? They would begin to give off vapour; they would gradually dry and shrivel up.

If I weighed them before and afterwards, I should find a great difference in their weight. The **potato** would lose **about 75 per cent** (three-quarters) of its weight, the **turnip** no less than **90 per cent.**

What does this show? That all these fresh vegetables contain a large amount of water.

Whence did they get this water? The roots of the growing plant absorbed it from the soil.

Lead up from this to the fact that water is a solvent, that it dissolves mineral matters out of the soil, and that these mineral matters are absorbed into the structures of the growing plant with the water.

It is more perhaps for their value as store-houses of

mineral matter than for their other properties that fresh vegetables are so important to our health and well-being.

One important mineral, **potash,** is always found in some form or other in carrots, turnips, and parsnips, radishes, asparagus, water-cress, lettuce, and endive.

Potash is chiefly valuable for its **antiscorbutic properties,** *i.e.* it prevents scurvy and other eruptions of the skin.

People who are deprived of these fresh vegetables are sure to suffer from scurvy.

Soda, lime, common salt, and the salts known as phosphates are all equally necessary, and find their way into the system in a similar manner.

Show some specimens of the minerals named. Tell that the water we drink always contains some dissolved mineral matter.

Refer to the furring of the kettle, and explain what it means. The gluten of the corn grains contains phosphates. Common salt is a great aid to the digestion of the food in the stomach. It is very essential that all food should be salted, both in the cooking and at the table.

IV. Fruit

The great value of the varieties of ripe fruits lies in the fact that their juices contain sugar, and (as in the case of vegetables) certain mineral matters.

They form a pleasant and agreeable change of food, and are most valuable to the system when ripe and sound. Unripe fruit should never be eaten unless cooked; unsound fruit should never be eaten cooked or raw.

V. Sugar

Sugar and starch serve, as we have seen, the same purpose as food. All starch must be converted into sugar before it can be of any use in the body. Sugar at once passes into the blood. It contains no flesh-forming element, and is valuable only as a heat-giver.

Refer to some of the earlier lessons, and lead the class to tell what they can of the growth, preparation, and refining of sugar.

Lesson XVIII

A MIXED DIET

I. Summary

Our lessons thus far have taught us that whatever we take as food must contain flesh-forming, heat-giving, or mineral matter.

Let us try now to summarise what we have learned in connection with the more common articles of diet.

1. **Flesh-formers.**—*Lead the class to give the names of the flesh-formers, and their sources, whether from the animal or vegetable world.* **Albumen, fibrin, gelatine,** *and* **casein** *are obtained from animal substances;* **gluten** *and* **legumin** *from certain vegetable substances.*

The following table should be set out on the black-board, and copied into the class note-books:—

Albumen	is found in	Flesh-meat	about 3	per cent.
	,,	Eggs	,, 17	,,
	,,	Fish	,, 5	,,
Fibrin	,,	Flesh-meat	,, 20	,,
	,,	Fish	,, 15	,,
Gelatine	,,	Bones	,, 40	,,
	,,	Fish	,, 7	,,
	,,	Flesh-meat	,, 7	,,
	,,	Isinglass	,, 80	,,
Casein	,,	Milk	,, 5	,,
Gluten	,,	Wheaten flour	,, 12	,,
	,,	Oatmeal	,, 18	,,
	,,	Rice	,, 6	,,
Legumin	,,	Peas	,, 23	,,
	,,	Beans	,, 25	,,

Potatoes and green **vegetables** contain about **1** per cent of flesh forming matter.

2. **Heat-givers.**—*Make the class tell that these consist of* **fats, starch,** *and* **sugar.** *The first are obtained from both the animal and the vegetable world; the two others only from vegetable matter, except in the case of milk.*

Fat (animal) is obtained from	Butcher's meat—	
,,	Mutton	about 45 per cent.
,,	Beef	,, 30 ,,
,,	Pork and Bacon	,, 50-70 ,,
,,	Butter	,, 87 ,,
,,	Cheese	,, 25 ,,
,,	Red Herrings	,, 12 ,,
,,	Eggs	,, 10 ,,

Fat (vegetable) is obtained from	Cocoa	about 45 per cent.
,,	Oatmeal	,, 5 ,,
,,	Wheaten flour	,, 1 ,,
,,	Peas and Beans	,, 2 ,,

Potatoes and rice contain a mere trace of fat.

Starch is obtained from	Rice	about 75 per cent.
,,	Oatmeal	,, 50 ,,
,,	Wheaten flour	,, 60 ,,
,,	Peas and Beans	,, 35 ,,
,,	Potatoes	,, 15 ,,
Sugar is obtained from	Cows' milk	,, 5 ,,
,,	Ripe Fruits	in variable quantities.
,,	Oatmeal	,, 5 ,,
,,	Wheaten flour	,, 5 ,,
,,	Peas and Beans	,, 2 ,,
,,	Potatoes	,, 3 ,,
,,	Beetroot	,, 10 ,,

II. What to eat

It has been ascertained, by most careful experiment, that an ordinary working man requires for his daily support about the following quantities of dry food-substances.

Flesh-forming material	4½ ounces.
Fatty matter	3 ,,
Starch and sugar	14 ,,
Mineral matter	1 ,,
Total .	22½

It should be borne in mind that as ordinary food contains on an average about half its weight of water, the actual quantities would be double those given.

Now let us imagine such a man trying to live on potatoes alone. Potatoes, as we have seen, contain only about 1 per cent of flesh-forming matter, and about 15 per cent of starch. In order, therefore, to get his proper quantity of flesh-forming matter (4½ ounces), he would have to eat an enormous amount (67 ounces) of heat-giving food (starch)—more by far than he requires, or could digest.

On the other hand, if he tried to live on beef alone, he would find that in order to get the requisite amount of heat-giving food, he would be compelled to eat very much more meat than he could possibly digest each day.

So it would be if he tried to live on bread, peas, beans—any one single food-substance.

Hence it has been found advisable, both on the score of health and also for economy, to have a mixed diet.

Call attention again to Nature's two model foods, milk and eggs.

Show that in each of these the food-store is laid up on the principle of a mixed diet.

The little animal finds just the requisite amount of tissue-forming material to build up its body, mixed with just enough fuel, or heat-giving food, to keep up the bodily temperature, and supply the necessary strength and energy.

There is no waste, no over-feeding, and yet when the work is accomplished and the little chick is ready to come out of the shell, the whole of the food has disappeared.

Let the class give examples of common mixtures, and tell the reason why such substances are chosen to accompany each other.

Meat and bread or meat and potatoes	Meat rich in fibrin and albumen	flesh-formers
	Bread and potatoes rich in starch	heat-giver
Bread and cheese	Cheese rich in casein	flesh-former
	Bread rich in starch	heat-giver
Liver and bacon	Liver rich in albumen	flesh-former
	Bacon rich in fat	heat-giver

Bacon and peas or beans	Bacon or pork rich in fat	heat-giver
	Peas and beans rich in legumin . . .	flesh-former
Rice, sago, tapioca, or corn-flour puddings with eggs and milk	Rice, sago, tapioca, and corn-flour rich in starch	heat-giver
	Eggs and milk rich in albumen and casein .	flesh-formers
Eggs and bacon	Eggs rich in albumen	flesh-former
	Bacon rich in fat	heat-giver
Suet-pudding with sugar or treacle	Wheaten flour contains gluten . . .	flesh-former
	Suet contains fat	heat-giver
	Sugar contains sugar	heat-giver

Lesson XIX

CLOTHING

I. Introduction

Our recent lessons have taught us that we take one kind of food for the simple purpose of keeping up the bodily temperature.

Whatever the actual material of such food may be—fat, starch, or sugar,—**it is simply fuel; it is burned up in the body, and its burning produces the requisite amount of heat.**

Our business now will be to learn that the great purpose of clothing is to regulate this bodily temperature, which the internal burning is always producing.

Perhaps if I were to ask you why we wear clothes, you would reply, "To keep us warm."

That would not be a good answer. I shall soon show you that clothes have sometimes to keep us cool.

I want you to think over some of our lessons on heat.

You remember, no doubt, that certain substances are remarkable as **good**, others as **bad conductors of heat; some as good absorbers and good radiators,** others **bad absorbers and bad radiators.**

Let the class themselves compare, as far as they can, woollen, silk, fur, linen, and cotton materials in these respects.

Notice too the different effect in light and dark coloured materials.

In the cold winter weather we are desirous of keeping in all the internal heat we can. Hence we clothe ourselves in non-conducting materials, such as **furs, flannels, and woollen dresses.**

In the heat of summer, when we wish to be cool, we exchange our furs and flannels for **light-coloured, thinner garments of good conducting materials.** These allow some of the internal heat to pass away and escape into the air.

In tropical climates white calico, holland, and linen are the usual materials for clothing.

Why white? Light-coloured materials, like bright, polished surfaces, reflect the rays of heat poured down upon them from the sun, instead of absorbing them. Such clothing, therefore, serves a double purpose. **It throws back the heat-rays which come from the sun,** and **it allows some of the bodily heat to escape into the air.**

Some clothing, you see, is for the distinct purpose of keeping the body cool.

II. Sources of Clothing

We obtain the materials for our clothing from both the animal and the vegetable world. From the former we get wool, fur, leather, and silk; from the latter, linen and cotton.

1. Animal Substances

(*a*) **Wool.**—Wool is the natural covering of the sheep. The wool is shorn from the animal, during its life-time, every spring.

Wool differs in quality and characteristics. English wool has long coarse fibres, and is usually known as **long wool.** From it are made flannels, blankets, worsted goods, and stuffs such as moreens, merinos, etc.

The wool imported from Australia and Saxony is of a

different kind. Its fibres are comparatively short, but fine, soft, and silky. This class of wool is used in the manufacture of broadcloth and other materials, mostly for men's wear, and commonly known as **woollen goods.**

Lead the class to tell that in winter the outer garments should be made of some woollen or worsted fabric, and why.

(*b*) **Fur.**—*Make the children give a list of fur animals, the teacher adding to the list when they fail*—e.g. *the rabbit, hare, squirrel, cat, ermine, sable, marten, racoon, badger, black and silver fox, otter, beaver, seal, bear, etc.*

Let them describe this sort of covering. It really consists of fine soft hair; the hairs being set extremely thick on the skin, so as to form a smooth, close coat.

Show a piece of fur. Feel it. It seems warm. Is it warm? Why does it feel warm?

Hair is a bad conductor of heat. Most of these animals live in the cold regions of the earth. This thick fur coat is a wise and beneficent provision of nature.

Tell that in the summer, when they no longer want their thick coat, much of the hair falls out and is shed, leaving the rest loose and open; but before winter returns a new supply grows, and the coat becomes again thick and close.

Refer them to the cat.

These furs can only become of use to us after the animal is dead. The skin, with its fur coat, is taken from the animal, and dressed without removing the fur. The man who prepares the skin is called a **furrier.**

(*c*) **Leather.**—Leather is made from the skins of certain animals. The hair is removed, and the skins are dressed with various substances.

Tell that in their raw state, as mere skins, they would, like all other animal matter, decay and rot. One object of the dressing is to change the perishable skin into a durable and comparatively imperishable leather. The dressing also renders it soft and pliable, and at the same time waterproof. No other substance, therefore, is so suitable as a covering for the feet.

(*d*) **Silk.**—Silk, the softest and most costly of all materials, is the product of the caterpillar of the silk-worm

moth. During the change from the caterpillar to the moth, the chrysalis spins its cocoon of soft, glossy fibres. These fibres are spun and manufactured into the silks and satins and velvets of commerce.

Test a piece of either of these substances by laying the hand on it, as we did on the wool and the fur. We notice the same thing. It feels warm. What does this tell us?

2. Vegetable Substances

(*a*) **Linen.**—*Show a piece of linen. Make the children tell, by reference to their earlier lessons, all they can of its history, properties, and uses.*

Lay the hand on it. It strikes cold. Is it cold? Place the thermometer in the piece of fur; note the temperature. Now remove it, and wrap the linen round it.

What do we find? There is no change in the position of the mercury.

What, then, does that show? That the fur is not warmer than the linen; nor the linen colder than the fur.

Why, then, do they appear so? Linen is a very good conductor of heat.

As an article of clothing it keeps the body cool, by allowing the superfluous heat to pass away. It is used chiefly for shirt-fronts, collars, and cuffs. It is too expensive to be used for the entire garment, except by wealthy people.

(*b*) **Cotton.**—Cotton is a sort of vegetable wool. It is obtained from the seed-pods of a plant which grows in most of the warm countries of the world.

Show a picture of the cotton-plant, and, if possible, a specimen of a pod. Test the heat-conducting properties of a piece of calico side by side with the linen, the wool, and the fur. It feels colder than the two latter materials, but is actually warm to the touch in comparison with the linen.

It is a conductor of heat, but is not of such high conducting power as the linen. It forms an admirable material for clothing in hot climates, and being cheaper than linen is much in request.

Lesson XX

WASHING

I. Cleanliness in Clothing

Commence by leading the class to talk about the skin and its function of perspiration.

The skin throws off, in addition to the watery matter, a great many impurities of an oily, greasy nature. These, of course, are absorbed by the garments which are worn next to the skin; and such garments cannot be worn long without becoming contaminated and unfit for use. Not only so; the oily, greasy, soiled garment causes other particles of dirt floating about in the air to settle and stick to it, and it thus becomes unwholesome and offensive.

Nothing is so productive of disease as dirt, and hence the person with dirty skin and dirty clothes falls an easy prey to disease. Clothing, and especially underclothing, should be frequently changed and washed.

II. Materials for Washing

1. **Water.**—*Provide two bowls, one of rain, the other of spring or hard water. Say nothing of the difference; leave that to be shown.*

Put some small dirty article in each; let one of the girls soap and rub them. Call attention to the result.

In the one case the soap refuses to unite with the water. It floats about on the surface in white flakes, and the dirt will not move. In the other the soap forms a lather on the water, and seizes upon and dissolves the dirt particles, which disappear as the rubbing goes on.

Now why is this? The water in the first bowl came from the well or the pump. It is hard water. The other is rain or soft water.

Let the class, by referring to earlier lessons, tell the difference between hard and soft water.

All water that has passed through the earth has absorbed from it certain dissolved mineral matters—chiefly **lime** and **sulphur** in some form. It is the presence of these which gives the hardness to the water. Rain-water contains none of these mineral matters.

Make the class tell how it was formed. It is really distilled water.

The first essential, then, for washing is a plentiful supply of soft water; and the best soft water that can be obtained is that which nature provides in the form of rain.

Rain-water, however, is not always available, and it is often absolutely necessary to employ the ordinary hard water.

Such water can be **softened by the use of alkalies, such as soda, potash, or ammonia.**

Take some ordinary hard water, and show the action of soda on it. Make the class tell the nature of an alkali. Show its power of neutralising acids.

We lately learned that vegetable matter contains soda and potash. People in the country frequently save the ashes from their wood fires, and steep them in the water they intend to use for their next washing-day. This they call **setting the lye.** The alkalies from the ashes dissolve out in the water and soften it.

This is a very primitive, tedious, and troublesome process, and, moreover, people in towns do not burn wood.

2. **Soda.**—Soda is manufactured ready for use on a large scale from common salt, and also from the ashes of burnt sea-weed and other plants growing on the sea-shore.

Soda, as we have seen, neutralises the acids, and softens the water. It also cleanses the garments by dissolving the dirt particles and removing the stains. Care, however, is necessary in using soda, as it has a tendency to make the clothes a bad colour if not used in moderation.

Lead the class to mention some of the many preparations or washing powders which are sold to assist in the process of wash-

ing. All these contain soda, mixed with lime in some form. These, no doubt, whiten the clothes, and save labour, but the lime has an injurious effect on the materials washed.

3. **Soap.**—The principle of soap-making was dealt with in one of the earlier lessons.

Lead the class now to tell all they can about it.

Soap is made by boiling tallow or oil with some kind of alkali. A compound of soda and newly-burnt lime is generally used for this purpose. The boiling unites the dissolved fat with the alkali, and makes a new substance —soap.

Refer to the old illustration of cleansing a dirty, greasy bottle by filling it with hot soda-water. The soda dissolves the grease, and unites with it to form a sort of soap, the dirt particles passing away with the grease.

This is exactly the work which soap does in washing. Compare.

II. The Work of Washing-Day

The good laundress always sorts out and soaks her clothes the day before they are to be washed. A tub of warm water, in which some soap and soda have been dissolved, is provided; and the garments, with their dirty parts well rubbed with soap, are pressed into it one by one. **Coloured things, likely to run, should not be soaked.**

The work of the day should commence early, in order that the best part of the day may be available for drying purposes. The first business, therefore, should be to fill the copper, and light the fire, so as to ensure a plentiful supply of hot water to begin the actual work.

The work of washing comprises three processes—rubbing, boiling, rinsing.

1. **Rubbing.**—The garments—every article on the outer side—should be well soaped and rubbed, one part against another. Care should be taken not to rub the hands or fingers, or the skin is likely to break.

When every part has been well rubbed in this way, the

garment should be turned inside out, and the water rung out of it. It should then be put into another tub of clean water and the process repeated, rubbing it this time on the wrong side. **Coloured articles and flannels must be washed without soda.**

2. **Boiling.**—When the rubbed garments are ready for the copper, some pieces of soap should be cut up and put into the boiling water, and the blue bag should be squeezed in it, to give the things a good colour.

Many "coppers" are made of iron, and unless great care is used will iron-mould the clothes. It is a good plan in such cases to make a linen or canvas bag large enough to fit the vessel, and to boil the clothes in this bag without allowing them to touch the iron at all. **Coloured things must not be boiled, as they are likely to fade; neither must flannels, because they shrink in boiling water.**

3. **Rinsing.**—The colour of the garments, especially the white ones, depends much on the rinsing. They should be well rinsed twice. First in clean cold water, and then in fresh water, in which some blue from the blue-bag has been dissolved.

All cotton and linen things should be well wrung before they are hung out to dry. **Flannels must not be wrung at all, as they are likely to shrink; they should be squeezed lightly and shaken.**

Coloured things will not run if a handful of salt is thrown into the rinsing water.

Muslin should be rinsed in alum water, as this is a prevention against fire. Should the muslin dress or curtain catch fire, it would then only smoulder instead of bursting into flame.

All articles should be thoroughly rinsed from soap, or the ironing process will scorch them, and turn them yellow.

Great care should be taken to see that lines, pegs, and props are clean, as good washing may all be spoiled by carelessness in this respect.

They should be taken in immediately the drying is over, especially in towns, as the sooty particles in the air will make them dirty.

III. Folding, Starching, Ironing, Mangling

This part of the work should be commenced by turning the garments to the right side again, and sprinkling them with a little clean water; after which they should be folded, and allowed to stand aside so as to become damp all over, for unless they are damp, it will be impossible to iron them.

Some of the articles—especially the table-linen, sheets, and towels—are usually mangled; **but it is best to iron all articles of wearing apparel.**

No articles should be used or worn rough dry, as the rough surfaces quickly catch up the dirt, and they are soon unfit for use again.

The great reason for ironing and mangling is to give the things a smooth surface.

A little wax, loaf-sugar, or borax put into the starch will prevent it from sticking to the iron, and will also help to give the article a smooth, polished surface.

LESSONS FROM BIOLOGY

(BOYS AND GIRLS)

Lesson XXI

ECONOMIC PRODUCTS OF PLANTS—A RECAPITULATION

Our lessons on plants and their uses have, from the first, led us to see that each is useful in its own particular way—one supplying food, another material for clothing, a

third timber for building purposes, a fourth yielding its valuable sap, and so on. We shall now proceed to extend our investigations in this direction, but before doing so, it will be well to systematise what we have already learned as to the uses of plants.

I. For Food

1. Chief among the food-supplying plants are those known as the **corn-grasses** — wheat, oats, barley, rye, maize, rice.

Make the class tell the comparative values of these different cereals as food.

Each contains two valuable food-stuffs. What are they? **Starch** and **gluten.**

Why is wheat more valuable for bread-making than barley or rice? Because it contains more gluten.

Make the class tell the properties of gluten as a food-stuff.

2. **Pulse.**—Peas and beans rank next in value to the cereals as food. They too consist largely of starch; but what other substance do they contain? **Legumin.** This gives them the name of **leguminous seeds.**

3. **Starch.**—The corn grains and the seeds of pulse all contain a large part of their bulk as starch. But there are some food-producing plants that yield nothing but starch.

Lead the class to tell all they can of **sago, arrowroot,** *and* **tapioca**—*their general appearance and properties—their value as articles of food—and the way in which they are each prepared from the plants which produce them. They are pure starch-foods.*

By far the greater part of the solid matter of the potato and of our green vegetables is this same substance —starch.

But there are certain articles that appear on our breakfast tables every day, not in the form of eatables, but as beverages. What do I mean? **Tea, coffee, and cocoa.**

We must take an early opportunity of learning something about each of these.

II. For Clothing

Certain plants supply materials for textile or woven fabrics. Name them. Flax, hemp, jute, cotton.

Which part of the plant in each case supplies the material required? Flax, hemp, and jute are obtained from the "bast" or inner fibrous bark of the plant; cotton from the seed-pods.

We shall deal with cotton in a later lesson. I want you now to tell me all you can about the other three.

Recapitulate from the former lessons. Make the class describe the flax-plant—its stem, leaves, flowers, and seed-pods; its habitat, and mode of cultivation; the preparation of the ripe stalks, by the processes of **rippling, retting, scutching,** *and* **heckling;** *the nature of the long, silky fibres after heckling; and, in a general way, the work of spinning and weaving.*

Hemp.—*Lead them next to describe the* **hemp-plant,** *and its relation to the common nettle; its habitat, cultivation, and preparation; the strong, tough nature of its bast fibres; their fitness for making strong, coarse fabrics—*e.g. *canvas and sail-cloth, as well as ropes, cables, and cordage of all kinds.*

Jute.—*Deal with this material in the same way. This too is a bast fibre, but is obtained from the inner bark of a plant belonging to the same class as the lime-tree.*

Compare the "bass" or bast fibres of the common lime, which are used in the manufacture of mats, etc.

Describe the nature of the fibres—soft, smooth, and silky. Jute is now used largely in the manufacture of textile fabrics; but it is less strong and durable than either flax or hemp. It is grown largely in India, and used there principally in the manufacture of a rough fabric for making "**gunny bags**" *for packing purposes.*

III. For their Stems and Bark

Lead the class to describe the nature of the "**exogenous**" *and* "**endogenous**" *stems.*

Each is useful in its own particular way to the people among whom it grows.

The natives of the East Indies and other tropical regions make great use of the stems of the palms, bamboos, and canes, which grow in luxuriance there.

The bamboo, for example, supplies the people of China not only with material for building their houses, but also for furnishing them with almost every conceivable requisite for their daily life.

The stems of our great exogens supply us with many varieties of timber.

Lead the class to tell the uses to which we put these varieties of timber, and their individual fitness for the purpose—e.g. *for ship-building, house-carpentry, furniture, machinery, ornament, toys, etc. One great difference between the exogens and endogens is that the former have a covering of bark, which the latter have not.*

Let them tell of the nature of **cork**; *of the manner in which it is stripped from the tree; of its uses in the arts and every-day life.*

It is the bark of a small evergreen oak which grows chiefly in Spain and Portugal.

Oak-bark, *and its employment in the preparation of leather, should be touched upon. It will be dealt with more fully in a later lesson.*

IV. For their Sap

Make the class tell the nature and purpose of the sap in plants—whence it comes—why it travels upwards to the leaves, and down again—what becomes of it, and so on.

We have already dealt with some of the substances derived from this source—sugar, india-rubber, and gutta percha.

Lead the class to tell all they can of each of them now.

1. **Sugar**—obtained chiefly from the sugar-cane.

Have it described—stem, joints, leaves, flowers, sap. Its habitat, mode of cultivation, and harvesting may follow; and then

the work at the sugar-mill and the boiling-house—raw sugar, molasses, loaf-sugar, golden syrup.

2. **India-rubber.**—Also a sap, but of a totally different nature. A thick white milky fluid found in the stem of several tropical trees.

Tell the mode of obtaining the milky sap—the action of the air upon it—and the nature of the raw material. Follow next with its uses in the arts and everyday life, as dependent upon its special properties. The making of elastic, vulcanized india-rubber, and the compound used for combs, ornaments, watch-chains, etc., might follow.

3. **Gutta percha**—a sap similar to that of the india-rubber tree—how obtained—hardens on exposure to the air—its properties and uses.

N.B.—*If this should be found too much for the time of one lesson, it would be well to spread it over two—rather than proceed to the new work without some such careful recapitulation.*

Lesson XXII

TEA

I. What it is

Show some specimens of tea, as supplied by the grocer. Tea is so common an article in every home that it will not be necessary to examine it closely in its present state.

Hand a few grains round the class to be tasted, and let the children notice the peculiar flavour. It has an astringent taste.

Tell the meaning of the word.

Put some into a cup, and pour boiling water on it. Let the class note the change that takes place.

The water first assumes a straw-coloured tint, then becomes brown; and the more tea there is in the cup, the darker will the liquid be.

Tell that we have made an **infusion** *of tea. That is, the*

tea has not merely coloured the water, but the water has drawn from the tea its peculiar properties.

Hand the cup round, and let the class compare the odour of the infusion with that of the dry tea. When it is sufficiently cool, let it be tasted. The infusion has the flavour as well as the odour of the tea.

Now pour off the liquid, and show what is left behind in the cup.

We have a heap of brown leaves. Each little grain of tea has uncurled and opened out, and we now see that it was only a leaf rolled up.

Spread one or two of the most perfect leaves carefully on a sheet of blotting-paper, so that they may be examined and described by the children.

The leaves are lance-shaped—that is, long and oval with sharp-pointed ends. They vary in length; some leaves are two, some three, and others four, and even five inches long.

Notice the finely-toothed edges of the leaves, like the edge of a saw. We describe such a leaf as **serrated**—a word that signifies "**saw-like.**"

Show a few common specimens of other serrated leaves for the sake of comparison—e.g. *the rose, lime, apple, and strawberry leaf.*

II. Its Value as a Beverage

We all know what a refreshing effect a cup of tea has upon us when we are tired and weary. Indeed nothing seems to do us so much good, and yet no one has, hitherto, been able to find out exactly how tea refreshes us. It contains **a volatile oil,** which seems to act upon the nervous system **with a soothing, quieting effect**; while at the same time it assists the work of respiration and perspiration, and thus has a cooling effect on the body.

This, however, is only the case when tea is drunk in moderate quantities; for it produces the opposite effect of sleeplessness if taken in large quantities.

In making tea **it should never be boiled,** because the

boiling carries off the volatile oil (the most valuable constituent). The proper way is to first warm the tea-pot with a little hot water; then put in the tea according to the number of persons who require to take it; and then pour boiling water on it.

A cosey, made of wool or feathers, will, by keeping the heat in, help to draw the tea quickly. It should never be allowed to stand a long time, for after a while it draws from the leaves a peculiar substance called **tannin**, which is injurious to the work of digestion.

III. The Cultivation of the Tea-tree

The tea-tree is a native of China and Japan; and it is now extensively grown in India and Ceylon.

Show a picture of the plant.

Tell that it is an evergreen bush or shrub; it is not allowed to grow more than three or four feet high. It bears long, pointed leaves, of a bright, deep green colour, with jagged, saw-like edges.

The leaves are the same colour at all seasons of the year. It bears beautiful white flowers with yellow stamens, and these are succeeded by the fruit, a kind of dry pod, containing three seeds.

The tea-plant will not grow except in a warm climate, and it flourishes best on the side of a hill, provided the soil be rich and deep. The plants are usually placed in rows about five feet apart, so as to enable the pickers to walk between them when the leaves are ready to be gathered.

In China the plants are mostly raised from seed, and no leaves are plucked for the first three years. After this there are three crops every year, as long as the tree lives.

IV. Preparation of the Leaves

1. **Picking.**—The picking of the leaves requires much care. Each leaf has to be picked separately with the

finger and thumb, and in such a way as neither to bruise the leaf itself nor injure the tender young shoots of the tree.

A picture of the tea-plantation, with the men, women, and children busy picking the leaves, would be interesting here.

The first picking takes place in April. This crop consists of the young tender leaves of spring, with the first bloom on them. They produce the finest and most delicately flavoured teas of the year.

The second crop follows in about a month. The leaves are larger, less bright in colour, and not so rich in flavour.

The third crop is picked when the leaves have reached their full size.

These two last crops furnish most of the tea sent out of the country—for the Chinese rarely part with any of the first crop. This they keep for themselves and their friends.

An acre of ground contains, on an average, about two thousand trees, and the annual crop is from 250 to 300 lbs. of tea.

2. **Drying.**—The first step in the preparation of the leaves is to expose them to the action of the sun and air for two or three hours. For this purpose they are either laid on mats or in wide shallow baskets, and stirred every now and then.

Show an ordinary leaf of any kind that has been treated in a similar way. Let the children describe it, comparing it with a fresh leaf. It has lost its crisp, brittle feel, and has become limp and flabby. Roll the two between the fingers and thumb. Which rolls best?

Now make the class tell the object of this drying of the leaves of the tea-plant.

3. **Rolling.**—The leaves, when sufficiently dried, are first rolled loosely by the hands on a flat table, and then thrown, a small quantity at a time, into an iron pan, over a charcoal fire, to complete the drying process.

While in the pan they are kept constantly stirred to prevent scorching, and, when quite ready, are swept quickly

on to the table, where the **twisters** complete the work of rolling, by rubbing the leaves between the hands while they are still hot.

In the finest and most delicate kinds of tea every leaf is rolled or twisted separately.

4. **Roasting.** — The final process is to throw the twisted or rolled leaves again into the pan over the charcoal fire, and carefully roast them, so as to drive off every particle of moisture. The utmost care is necessary, as before, to prevent scorching.

Nothing now remains but to sift and sort the tea, and pack it in chests lined with lead-foil for the market. What is the object of the lead-foil ?

Black and green tea.—*Show some of each. Both are made from the same leaves from the same tree.*

In the preparation of the green tea the leaves are dried and rolled immediately they are gathered. For black tea the leaves are first thrown into a heap and covered with matting for some time, till they begin to ferment. The fermentation causes the green leaf to change colour and become dark, almost black.

V. Kinds of Tea

Among the black teas the finest are **Pekoe** and **Souchong.** These are prepared from the early gatherings. The second or main gathering gives **Congou,** which forms the bulk of the better supply that reaches us. **Bohea** is the name given to the latest gathered crop. It forms the coarser, commoner, cheaper class of tea sold.

Hyson and **Gunpowder** are the best known of the green teas.

Show some of each. Explain from these specimens the difference between twisting and rolling. The Gunpowder is rolled up into little round balls. Hence its name.

Lesson XXIII

COFFEE

I. What it is

Show a little ground coffee. Let the class examine it and note its peculiar aroma and flavour. It is used in the preparation of a favourite and refreshing beverage.

Put some of the powder into a cup and pour boiling water on it. In a short time the water assumes the colour, flavour, and aroma of the powder itself—**we get an infusion.**

As a beverage it is most refreshing, especially when one is weary and drowsy with sleep. It then acts as a slight stimulant, rousing one to fresh activity, and resisting the desire to sleep.

Now let us see what this reddish-brown powder really is.

Show some roasted coffee-berries. Tell that the powder was obtained by grinding hard, oval berries, like these, in a mill. A small coffee-mill might be easily borrowed for the occasion, and the grinding process shown.

Let the class examine the berries.

They are of a dark brown colour, hard and somewhat brittle, for they break easily, and they have the same peculiar aroma and flavour as the powder has.

Let the children prove and tell this for themselves.

We call them **coffee-berries.**

But whence are these berries obtained? They are the fruit of a pretty evergreen tree which grows in the tropics.

II. Description of the Tree

Show a picture of the tree. Call attention to its oblong, pointed leaves of bright, deep, glossy green.

The tree, being an evergreen, keeps its bright, glossy foliage all through the year. It very much resembles the

laurel. In its natural or wild state it grows 15 or 20 feet high, but under cultivation it is kept well cut, and is rarely allowed to exceed 6 or 8 feet in height.

Notice the pretty white and rose-tinted flowers in the picture, not unlike those of the jessamine. Call attention to the profusion in which they are clustered round the branches, especially between the joints of the young twigs.

Most of the flowers burst out at one time, and so thick and close are they that the tree appears as though covered with snow.

Could we smell, as well as see, these flowers in the picture, we should find them to have a most delicious fragrance.

When the flower falls off, which it does as rapidly as it comes, it leaves behind the fruit—a small, dark red berry, not unlike a small cherry. It consists of a soft, pulpy, or fleshy part outside, with two hard, oval bodies or kernels in the centre. These kernels are the coffee-berries which we use.

Hand round some specimens, and let the class describe them. One side is rounded or convex, the other flat.

Tell that in the fruit the two flat sides lie together, and that each kernel is enclosed separately in a tough membrane or skin.

III. Cultivation and Gathering for the Market

The coffee-tree is a native of Abyssinia, where it may still be seen growing wild. As far back as the year 1454 it was introduced into Arabia, and it is now cultivated in nearly all the tropical countries of the world. It is grown most extensively in Brazil, the East and West Indies, and Ceylon.

The culture of the coffee-plant is very simple, and as a rule it will flourish in high lands which are unsuited to most other crops. It is a curious fact that plants grown in low, damp situations give a greater yield, but the berries are of inferior quality; while those grown in hilly districts produce less, but the quality is better.

The plants do not begin to yield till they are two years old, and, as a rule, the crop is only a moderate one for the next two or three years. After this, however, they continue to bear for about eighteen or twenty years.

Two pounds of berries is a good average yield for one tree annually.

As the berries ripen, the outer skin begins to shrivel up, and it is then time to gather them.

In Arabia the berries are not plucked but shaken from the tree. Of course only the ripe ones fall, and as they fall they are caught on cloths spread on the ground below. They are then laid in the sun and dried, after which they are placed in a trough, and made to pass between large revolving rollers.

The pressure of the rollers breaks the husk into small pieces, which are afterwards winnowed away. The berries, after being once more dried in the sun, are packed for exportation.

In Brazil, the West Indies, and other parts, the berries are plucked by hand as soon as they are ripe, and they are either dried in the sun, or the pulp is at once removed by crushing and washing between heavy revolving rollers in the pulping house. They are then carefully dried again and packed.

IV. Roasting

Show, if possible, some specimens of the different varieties of coffee-berry in the raw state.

The Arabian variety is smaller than the rest, and more round than oval in shape. Its colour too (a sort of dark yellow) is peculiar.

The East Indian variety is larger and of a lighter hue.

The Brazil berries are the largest of all, and their colour is a sort of greenish-grey.

Let the class take some of them in their hands and smell them. Break up one or two, and let them put the pieces in their mouths. They are not easy to break in this state, for they are rather tough.

Now we have seen that these berries are all alike in one particular. They have no fragrant odour, and no peculiar flavour like those we examined first.

Have the roasted berries examined again, and let the class note the difference.

Tell that the aroma and flavour are only acquired after the berries have been roasted. The roasting also renders the tough berry quite brittle. This too is an important change, as the work of grinding is to follow the roasting.

Describe the process of roasting. A close iron cylinder, something like a barrel, is fixed over a slow, gentle fire in such a way as to enable it to revolve constantly on a sort of pivot. The berries are placed in the barrel, and, as the roasting goes on, the constant turning of the cylinder brings them all in succession under the influence of the heat.

The roasting process is a very delicate one, as the whole flavour and aroma of the coffee depend upon the care with which it is done.

Properly speaking, coffee should be roasted and ground only as it is wanted for use, as it loses its delicate flavour if it is exposed. The next best thing is to keep the coffee after it is ground in well-corked bottles.

Lesson XXIV

COCOA

I. What it is

Show some samples of the various preparations of cocoa and chocolate. Let the class tell their uses.

These all come from one and the same source. We are going to learn what that is. But before we inquire what it is, it will be well to say what it is not. Cocoa is not made from the cocoa-nuts which we see in the fruiterers' shops. It has no connection with them or with the palm trees on which they grew.

Its real name is **cacao**, and it is the produce, not of a palm, but of a tree very like the English cherry-tree. This tree is a native of America. It was found growing there by the first European discoverers of the continent, 400 years ago. The Indians called it cacao, and they used it, as we do now, for the preparation of a refreshing beverage.

It is now grown extensively in the West Indies and in Central and South America, and it has lately been introduced into some of the tropical countries of Asia and Africa.

II. Description of the Tree

The cocoa-tree, in its natural or wild state in the forests of Demerara, grows to the height of 30 feet, but in cultivation the pruning-knife keeps it down to the size and shape of an ordinary cherry-tree.

It is an evergreen, the leaves being very similar to those of the cherry, except that they are very smooth and glossy, as is the general case with evergreens.

The tree does not begin to bear till its sixth year, but after that it is very prolific. The flowers, which are small, grow in thick clusters on the trunk and main branches. The fruit is a kind of oblong pod, from 7 to 9 inches in length, and 4 inches in breadth. It is covered with a thick outer rind, which takes various colours as it ripens—yellow, red, purple.

The tree presents an unusual and interesting appearance, as it bears at the same time leaves, buds, flowers, and fruit.

Picture the tree with its bright, glossy green leaves, buds in all stages of growth, thick clusters of pretty flowers, and fruit-pods, some yellow, some red, some purple.

Great care is necessary in the cultivation of the cocoa-tree. Rich soil, a hot, moist climate, and shelter from cold winds are all required.

III. The Pod

The pod is a hard, tough, woody case, smooth on the outside, oblong in form, and somewhat pointed towards the end. It is divided lengthwise into five compartments or cells by thin woody partitions, which spring from a central core. We call such a pod a **capsule.**

Show a poppy-head, or, if possible, the dried seed-vessel of a tulip. These will convey a correct idea of a capsule.

In each cell several seeds or nuts are packed closely together round the central core, and embedded in a pinkish-white pulp.

Compare the seeds and pulp in the orange, which is really a sort of capsule.

There are in all from 20 to 40 seeds in each pod. These seeds are the cocoa-beans which we use.

Show a few specimens. They are about the size of a small bean, and when removed from the pod have a thin, dark brown, brittle shell. The kernel, which is of the same colour, contains half its weight of oil, which may be easily squeezed out.

From what we have already said, it will be seen that there are always some ripe pods on the tree, but the principal gathering is in December, with a smaller crop the following June.

IV. Preparation of the Nuts

The first process in preparing the newly-gathered nuts for the market is to induce them to ferment. This is usually done by burying a heap of them in the earth for about two days. They are then taken up and laid in the sun to dry, after which they are roasted in revolving metal cylinders just as coffee is roasted.

The roasted beans are next crushed and broken up into small pieces, usually known as cocoa-nibs. All that now remains is to winnow away, or pick out with the hands, the little broken fragments of loose shell.

Some people prefer to use the cocoa-nibs themselves in the preparation of the beverage. They make excellent cocoa, but they require careful boiling for some time. They give out a very large amount of oil, which may be seen floating on the surface of the liquid when it is cooked. Cocoa is more frequently used in the form of thin, flaky slices. In this state it is known as **flaked cocoa.**

Show some samples.

It is prepared by grinding the nibs to a very fine powder, mixing it with water into a paste, rolling the paste into thin sheets, and then allowing it to dry and harden.

The commonest form in which cocoa is used is that known as **soluble cocoa.**

Show some of this kind.

In the preparation of this, the cocoa-beans are first pressed, to extract all the oil, and then ground into a fine powder, with a certain quantity of starch. This kind of cocoa thickens when boiling water is poured on it. It is really the starch and not the cocoa that thickens.

Illustrate by pouring some boiling water on a small quantity in a cup. Refer to former lessons, and make the class tell why the starch acts in this way.

Chocolate is the highest form in which cocoa is prepared. The nuts for this purpose are treated as if for ordinary soluble cocoa, except that they are mixed with a certain quantity of sugar and starch, and the whole is then ground into a soft, smooth paste on hot metal tables. In this form, with, generally speaking, a little flavouring matter added, it is moulded into sticks, cakes, balls, etc., which are sold at the confectioners' shops under the name of chocolate-creams.

The name **chocolate** is our form of the Mexican word **chocolatl,** the name by which the prepared cocoa-bean was known by these people before Europeans visited them.

Cocoa is a most valuable beverage; it contains more tissue-forming matter than any other.

Lesson XXV

VEGETABLE OILS

I. Introduction

OILY matter of some kind is met with in most plants. It is found in various parts of the plant, but as a rule is most abundantly stored away in the fruit and seeds.

Lead the class to think of the germinating seed and what it is that feeds the embryo, till it is able to seek its own living from the soil. The store of oily matter is one form of that plant-food.

Linseed, hemp-seed, cotton-seed, rape, colza, castor, and poppy oils, are all obtained from the seeds of plants; palm and olive oils from the fruits; cocoa-nut oil from the nut of the cocoa-nut palm.

Hold an ordinary almond in the flame of the spirit-lamp.

It takes fire readily and burns with a flame. Why? It contains 46 per cent of its weight in oil. It is this oil that burns.

Oils are usually extracted by pressure, and are then known as **cold-drawn oils**—that is to say, the oil has been obtained without heating.

Sometimes heat is employed as well as pressure; and many oils of a peculiar nature, such as oil of turpentine, peppermint, lavender, rosemary, can only be obtained by **distillation.**

II. Fixed and Volatile Oils

Take some pieces of clean white blotting-paper, and let fall on one a drop of some common oil, such as olive, colza, or castor. Now drop a similar quantity of oil of peppermint on another. Wave the papers about gently, and let the class note what follows. On the first sheet they will see a widely-spreading, greasy stain—the oil remains. No mark or stain is to be seen on the other.

The oil of peppermint has flown off and disappeared, leaving no trace.

Tell that we call the first a **fixed,** *the other a* **volatile oil. Volatile** *comes from a word that means "to fly."*

Oil of linseed, hemp, cotton, rape, colza, castor, poppy, olive, palm, and cocoa-nut all belong to the first class, or **fixed oils.** Oil of turpentine, lemon, lavender, bergamot, rosemary, and peppermint are among the **volatile oils.**

III. Uses

Each of these vegetable oils is useful in its own particular way, and the uses to which we put them depend entirely on their individual properties.

1. **Linseed-oil.**—This is one of the products of the flax-plant.

Lead the class to describe the plant, which has already been dealt with in a previous lesson.

The seeds (show some) contain one-fourth their weight of oil, which is obtained by pressure between closely-fitting iron rollers.

The crushed seeds themselves are pressed into "cake," and make a valuable food for cattle. The price of this oil-cake varies from £10 to £12 a ton. Linseed-meal is used in the sick-room for poultices.

This oil is largely used in the preparation of paint and putty, because it has the property of **drying very rapidly** when exposed to the air, in thin layers. We call it a **drying oil.**

Hemp and poppy oils are obtained in the same way, possess the same drying properties, and are applied to the same uses as linseed-oil.

2. **Rape and colza oils.**—These are obtained from the seeds of the **cole** or **rape** plant, a member of the cabbage tribe, which is grown largely in India and southern Europe. The seeds contain 40 per cent of their weight of oil, which is obtained by pressure.

All oils are very inflammable.

Apply a lighted match to pieces of paper dipped in various oils.

Rape and colza oils are the best of all the vegetable oils in this respect. They burn with a bright luminous flame. They are easily extracted, and are thus cheap.

They are used in lamps, and burn without charring the wick. Best colza-oil is employed in the lamps of light-houses.

These oils have none of the drying properties of linseed and other oils, and would be unsuitable for the purposes to which they are applied; neither would linseed-oil be suitable for lamps.

3. **Castor-oil.**—This oil is obtained by pressure from the seeds of a plant that is a native of India, but is now grown in the south of Europe and America. In those parts of the world it attains the height of 20 feet. We may sometimes see it growing in England, but it is a comparatively small plant here, not reaching more than 3 or 4 feet in height.

The seeds are about the size and shape of a bean, and contain a large quantity of thick oil, of a very nauseous odour and taste.

We use castor-oil mainly as a medicine, but in India it is abundant and so cheap that it is burnt in lamps.

4. **Palm-oil.**—*Show some palm-oil and cocoa-nut oil.*

How do these differ from the oils we have already seen? These are solid, the others are liquid.

Tell that in the country where they are produced these oils are liquid too. It is only in our climate that they become thick and solid.

Compare butter in the summer and winter.

We are accustomed to speak of these solid oils as "**fats.**"

Show a picture of the **oil-palm.**

It grows to the greatest perfection in tropical Africa, where it reaches a height of 30 feet.

The fruit, from which the oil is obtained, grows in

bunches, often two or three feet across, each individual fruit being oval in shape, and varying in size from a pigeon's to a hen's egg.

When ripe they are quite smooth and of a bright golden-yellow. They consist of a small, hard nut embedded in a soft, oily flesh.

The oil is obtained by boiling the ripe fruit in earthenware pans, and then crushing the mass in wooden mortars.

It is mostly used in the manufacture of composite candles and soap, and for lubricating the axles of railway-carriage wheels. The natives of Africa use it as we do butter.

5. **Cocoa-nut oil.**—*Show a picture of the cocoa-nut palm. Describe its long, straight stem, towering upward often to* 100 *feet, and crowned with immense drooping leaves, each about* 15 *feet in length.*

It is cultivated in most tropical countries; especially in the East and West Indies, India and Ceylon, and in the islands of the Pacific Archipelago.

Show the fruit—the tough fibrous outer case, the hard woody shell, and the kernel.

The oil, which at ordinary temperatures is a white solid fat, is obtained sometimes by pressure, sometimes by boiling. It is largely used in the manufacture of soap and candles.

Tell of some of the other uses to which the natives apply the other parts of this, to them, most invaluable tree—the leaves, the sap, the fibrous husk of the fruit, the wood, etc.

6. **Olive-oil.**—*Show some olives.*

They are the produce of a tree that grows in the countries that lie along both shores of the Mediterranean.

Show a picture of the tree.

It is a small evergreen shrub, not more than 9 or 10 feet high, covered with long, lancè-shaped leaves, and bearing small, white, sweet-scented flowers. The fruit is like a small plum or damson.

Open one, and show the long, pointed stone inside.

Those which we have before us are green; they were

gathered before they ripened, and pickled green for dessert. When the fruit is allowed to ripen, it assumes a dark purple colour, and the flesh becomes oily and rough and bitter to the taste.

When the fruit is quite ripe, the oil is extracted by pressure in a screw-press. That which flows first, and with only a slight pressure, is considered the finest oil. It is known as **virgin oil.**

The commoner kinds of olive-oil are obtained by first heating the fruit, and then subjecting it to very strong pressure.

Show some olive-oil. It is commonly known as **sweet oil.**

It is a pale yellow, inodorous liquid, and is very inflammable. The best kinds are used in the preparation of food, although to a much more limited extent with us than in the countries of southern Europe, where it may be said to take the place of butter and cream, and is used at every meal.

Some of the commoner kinds are used in those countries for burning in lamps. We employ large quantities in the woollen and soap manufacture.

Lesson XXVI

VEGETABLE SECRETIONS—CAMPHOR AND GUMS

I. Introduction

Lead the class to talk about the sap of plants—its source, the soil in which the plant grows, and whence it is absorbed by the roots—its upward passage to the leaves—the action of sunlight and air on it.

Each plant takes up from the soil that which is required for its own special needs, and nothing more; and from this it elaborates by means of its leaves its own special secretion.

Our last lesson introduced us to a number of plants, which convert this sap into oily matter, and store it up in their fruit or their seeds.

Make the class give examples.

In some plants the sap is elaborated into a sweet juice, which is stored up either in the woody stem or the root, and when obtained and boiled yields sugar.

Make the children tell the plants referred to, and explain rapidly the process of obtaining sugar from the sugar-cane, maple, and beetroot respectively.

In other plants the sap becomes a white, milky juice, which flows in great abundance from the stem if the bark be wounded, and hardens into a solid mass on exposure to the air.

To what plants am I alluding now? The india-rubber and gutta-percha plants.

Make the class tell rapidly all they can of the preparation and uses of these two substances, the teacher helping where necessary.

There are many other varieties of vegetable secretions which produce substances of great usefulness to man. We shall deal only with one or two of the most important.

Lead the class to form some idea of the value of these products by telling that, exclusive of sugar, Great Britain alone imports annually upwards of £2,000,000 *worth.*

Among the most important are camphor, gums, resin, turpentine, tar, and pitch.

II. Camphor

1. **Properties.**—*Show a piece of camphor, and lead the class to tell by observation some of its more striking properties.*

It is a white, hard, tough, solid substance, with a very powerful odour, and a bitter, unpleasant taste.

Tell that, in its ordinary state, camphor is so volatile that a piece left exposed to the air would in a short time disappear altogether by evaporation.

Put a piece in water. It dissolves very slowly; so slowly that we might almost say that it is insoluble in water, were it not that it imparts some of its odour and taste to the water.

Place a piece in alcohol, and it dissolves rapidly, forming camphorated spirits or "spirits of camphor."

Pour this liquid into water, and the camphor, which was invisible, reappears in the form of white flakes.

2. **Uses.**—Insects of all kinds dislike the strong pungent smell of camphor. Little saucers of this substance are always kept, therefore, in cabinets of natural history specimens, to keep away insects. It is a good protection against moths to keep some camphor in the drawers with our furs, blankets, and woollen clothes of all kinds.

Camphor is used as a medicine; but it is a fallacy to think that it has the power of warding off infection. It is even a bad thing to wear camphor about the person, as it is weakening and lowering both to the muscular and nervous system. Three or four drops of camphorated spirits taken on a lump of sugar is often a good preventive of cold.

Camphor is obtained from a plant belonging to the laurel family. The camphor-laurel grows chiefly in China and Japan, where it is as large as an English oak; but it has lately been introduced into several of the warmer countries of the world.

3. **How it is obtained.**—It is obtained in a curious way.

Place a piece of camphor in the evaporating dish over the spirit-lamp. It at once begins to melt, but as it melts it passes off very rapidly as vapour. Camphor is a very **volatile** *substance.*

Hold some rough cold surface over the dish, and it will be soon covered with white powdery flakes, the condensed vapour of the camphor. This will make it easy to understand how the camphor is obtained from the tree which produces it.

The valuable secretion is found in every part of the tree—root, stem, branches, and leaves. When, therefore,

the tree is fully matured, it is uprooted, and every part of it chopped up into small pieces.

These pieces are then put into iron retorts, which are covered with boards pierced with holes, above which are placed large, dome-shaped hoods of earthenware. The hollow of the hood is filled with loose twigs, hay, or straw, and after all crevices have been stopped, the retort is placed over a moderate fire.

Now the class can tell all the rest from the little experiment that has just been shown. The heat causes the volatile camphor to rise in vapour, and when the vapour touches the cool, rough surface of the hay and twigs, it condenses on them in flaky crystals, and is afterwards scraped off.

It is now a dirty brown colour, and is known as **crude camphor.** It is purified by a second distilling process, somewhat similar to the first, and when it is again collected it is the hard, white, tough crystalline substance we have before us now.

III. Gums

1. **Properties and uses.**—*Show some* **gum-arabic,** *and lead the children to discover by observation its properties.*

It is colourless and nearly transparent; has a glassy lustre; is perfectly inodorous; and possesses an insipid taste.

Show some that has been in water a short time. It is gradually disappearing. It will after a time dissolve completely in the water and form a thick adhesive solution. This solution, as it dries, has strong stiffening properties.

It is on account of its adhesive and stiffening properties that gum is so extensively used in the arts and manufactures. It makes a valuable cement for attaching labels to glass and other objects.

It is largely used also in calico-printing, and in the manufacture of crape and other fabrics.

2. **How obtained.**—Gum-arabic is obtained from a tree of the acacia tribe, that grows chiefly in Arabia;

hence the name. It also grows in the East Indies, Abyssinia, and Egypt. It is an exudation from the stem, and hardens on exposure to the air.

Tell that our own plum and cherry trees may often be seen with similar gummy exudations, oozing through cracks in the bark.

Gum-Senegal is a similar though inferior secretion, and is much used in calico-printing.

Show a bottle of gum, used for ordinary cementing purposes, and tell of the gum on postage-stamps, envelopes, and labels.

This is not made of gum-arabic. It is a cheaper preparation, known as **dextrine** or British gum.

It is made by baking starch in a moderate heat until it assumes a pale brown colour. The baking makes it soluble in water; and when dissolved it forms a thick, adhesive solution, similar to the dissolved gum-arabic, but immensely cheaper.

In the preparation, a portion of sugar is usually added to the solution to render the cement easily softened by moisture.

Lesson XXVII

VEGETABLE SECRETIONS

I. Resin and Turpentine

1. **Properties and uses.**—*Show a piece of common resin. Let the children examine it and find out what they can of its properties.*

It is a yellow, solid substance, almost transparent. If we take it in our hands, we find it is somewhat sticky to the touch. It is very brittle, for it breaks readily with the blow of a hammer.

Put it in water; it does not dissolve. Tell that it is insoluble in water, but soluble in alcohol and the essential oils.

Illustrate this by placing a piece in a glass vessel containing alcohol, and standing it aside for a time while it dissolves.

Hold a piece in the flame of the spirit-lamp; it at once takes

fire and burns with a flame and much smoke. **It is highly inflammable.**

It is employed chiefly in the manufacture of soap, and also in the preparation of a common kind of wax, which is used for sealing the corks of bottles.

Show next, for similar examination, some oil or spirits of turpentine. Tell its name.

It is a clear, transparent, and very limpid liquid. It has a peculiar and powerful odour, and is highly inflammable, burning with flame and smoke.

Let fall a drop on a sheet of paper. It gradually passes away, leaving no stain.

What do we call such a liquid? It is a **volatile oil.**

What other name do we give it? It is also called an **essential oil.**

Make the class give the reasons for these names.

Oil of turpentine is the most valuable of all the "volatile" or "essential" oils. It is a powerful solvent of fat and oily matter of all kinds. Hence it is used to take out grease-stains in our clothes, etc.

It is lighter than water, and floats on the surface.

Because of its volatile character, it is largely used in making common oil-colours for painting. It helps the paint to flow freely from the brush; and when it is laid on, the turpentine flies off rapidly in vapour, leaving behind the substance of the colour, with the thin coating of linseed-oil.

What happens then, and why?

Large quantities of oil of turpentine are used in the manufacture of varnish, and it is also employed in making Brunswick black, for covering iron goods.

Tell that both these substances—the solid resin and the liquid oil of turpentine—come from the same source.

2. **Whence obtained.**—*Show a picture of a pine-tree. Let the class compare it, in its appearance and habit of growth, with other familiar trees.*

These trees are all alike, and their fruit is a dry, scaly cone.

Several species of these pine-trees elaborate a peculiar secretion—a thick, very sticky liquid, of a yellowish colour, not unlike honey in appearance.

It is obtained, in the usual way, by making incisions in the bark, through which the honey-like liquid flows, and is collected in vessels placed round.

This liquid is known as **crude** or **common turpentine.**

The great pine-forests of North America supply immense quantities of this crude turpentine—in fact, they supply the world. No less than 30,000 tons are imported annually into this country alone.

Distillation.—The crude turpentine is heated with a certain quantity of water in a copper retort or still. When the water boils, the steam passes away into the condenser to be re-converted into water, and the vapour from the heated liquid distils over with it.

This vapour condenses too, and forms a clear, limpid fluid, which, being lighter than water, floats on the surface. The new liquid when collected is the **volatile oil** or **spirits of turpentine.** In the retort itself a yellowish, solid substance is left behind. **This is the resin.**

The crude or common turpentine, therefore, consists of resin dissolved in oil of turpentine.

II. Tar and Pitch

1. **Properties and uses.**—We have already seen that tar is one of the off-products formed from coal in the manufacture of coal-gas. This is known as coal-tar. Here we have another kind of tar—not black like coal-tar, but of a dark brown colour. This is made of wood.

Let the children examine it and tell its properties.

It is a dense, heavy, sluggish fluid, having the consistency of treacle. It has a powerful smell, and a bitter, unpleasant taste.

Dip a splinter of wood into it and ignite. It burns with a right flame, but gives off volumes of dense smoke.

Let fall a small quantity into a vessel of water. It sinks to the bottom, and will not mix with the water.

It is insoluble in water. It is this fact that makes it so difficult to remove tar from the hands by washing.

It is soluble in spirits of turpentine, and in all fats and oils.

What do we do to remove tar-stains from the hands? We rub the hands well with either oil of turpentine or with grease of some sort, and then wash them.

It is this property of not mixing with water that has caused tar to be so extensively used in preserving wood-work and other substances.

We tar wooden sheds, fences, and the outside of ships. We steep the ship's cordage in tar; we tar sheets of canvas to make waterproof tarpaulings; and we steep in tar great beams of timber which are required to resist the action of water.

A wooden post is to be fixed in the earth. The lower part of the post is first steeped in tar. Why? The moisture in the earth cannot enter the wood to rot its substance, because it cannot mix with or pass through the outside coating of tar.

A well-tarred shed will last for many years in spite of rain. The rain simply runs off the tarred surface, and cannot penetrate. **Pitch** is a black, solid substance. It is very brittle, and when broken has a bright shining surface. It becomes liquid and boils with a slight heat. Like tar, it is impervious to water.

2. **Whence obtained.**—Tar and pitch, like resin and turpentine, come from the same source. Indeed, tar and pitch are the products of some members of the same family of cone-bearing trees whence we get resin.

The particular kind of pine which yields tar and pitch is known as the Scotch fir, and is grown chiefly in Norway, Sweden, and Russia. All our supply, amounting to about 30,000 tons annually, we import from these countries.

Tar, although a secretion, does not flow naturally from the tree like turpentine. It is stored up in the roots, and

the supply can only be obtained by the destruction of the tree.

The tree, when fit for the purpose, is felled, and the roots are cut up into small logs.

A circular pit, tapering towards the bottom, is next dug on a sloping bank or hill-side, the sides of the pit being beaten hard and smooth. The bottom of the pit is made to communicate by a pipe with a tank, placed below.

The little logs of pine-roots are then carefully packed in the pit. When it is full, a fire is lighted on the top, and as soon as the whole mass is fairly ignited, the mouth of the pit is covered with earth and turf. The burning goes on in a slow, smouldering sort of way, because it is smothered and confined.

The wood becomes charred and converted into charcoal, and a dense, treacle-like liquid runs downward through the mass and passes into the tank below. This is the tar of commerce.

Tar when heated in the retort distils over a volatile spirit, and leaves behind the black, solid substance—pitch.

Lesson XXVIII

COTTON

I. Introduction

[N.B.—*If this is found too long, the process of manufacture should be dealt with in a separate lesson.*]

Show a piece of calico. What is this? It is cotton-cloth. Tell that this is more extensively used for clothing by the people of all parts of the world than any other material.

Let the children examine it, and show from its properties that it is peculiarly fitted for this purpose.

It is soft, and easily worked; and it is warm to the

touch, although very light. When dirty, it can be easily washed.

Help them to name other textile fabrics made from the same material, showing specimens of each—e.g. *cotton-print, dimity, muslin, lace for curtains, etc., hosiery, fustian, corduroy, velveteen—all these are made from cotton.*

II. Cotton a Vegetable Production

Show, if possible, a cotton-pod with its seeds and cotton enclosed. Let the children examine the soft, white, downy wool.

This pod is the fruit or seed-vessel of the cotton-plant, and the downy wool is the material from which all our cotton fabrics are made. We may call it **raw cotton**, *i.e.* cotton just as it grew in the pod.

There are several varieties of the cotton-plant. One kind, which is cultivated chiefly in India and China, is a tree, and grows to the height of nearly 20 feet; another is a small woody shrub, about the size of an ordinary currant-bush. The plant which supplies almost all the cotton of commerce is an annual or herbaceous plant, which grows from seed sown every spring, comes to perfection and ripens, and dies down in the autumn.

This plant is cultivated largely in the United States, West Indies, Natal, Egypt, Queensland, and in almost all the warmer parts of the world. It succeeds in soils too poor for the production of other crops, provided only that the climate be dry and warm.

Show a picture of the plant. Call attention to the rich, dark green leaves, and the large, bright yellow flowers, with a purple spot in the centre.

When the flower dies, it leaves behind a pod similar to the one we have here. It is of a triangular shape, and about the size of a walnut. The seeds which it contains are embedded in the mass of cotton-wool.

Show some of the seeds. They are about the size of the seeds of a grape.

Are they of any use? When pressed, they yield cotton-oil and oil-cake.

When the plant is fully ripe, the pod bursts, owing to the swelling of the woolly matter within. It is then time to gather in the crop.

III. Preparation of the raw Cotton

1. **Picking.**—The work of gathering the ripe cotton is usually done by women and children, who pluck both seeds and wool together out of the pod. As it is gathered, it is carried away in baskets and laid out in the sun to dry. When quite dry, it is ready to be separated from the seeds. This is done by a machine called a **gin.**

2. **Ginning.**—There are several varieties of **gins.** That used in America is the best. It consists of a sort of box, the bottom of which is formed of strong parallel wires, about one-eighth of an inch apart. Between these wires a number of circular saws project upwards into the box, which is loosely filled with the newly-picked cotton. The saws are made to revolve by machinery, and as they turn, their teeth drag the cotton through the bars, leaving the seeds behind. Some of the seeds are saved for next spring's sowing; the greater part are crushed for the oil they contain.

3. **Packing.**—The cotton, thus freed from its seeds, is pressed by powerful machinery into great **bales,** each bale weighing about 350 lbs., and is then ready to be shipped to the manufacturer.

The raw cotton is not all of the same quality. One kind, which is more highly prized than all others for the length and strength of its fibre, is known as **long staple.** Its fibres are usually about an inch and a half long. The best variety of the **long staple** is that known as **Sea Island cotton.** It takes its name from the fact that it was first grown, and is still grown to greatest perfection, on some islands lying off the shores of Georgia, one of the southern states of America.

In the commoner sorts, known as **short staple,** the fibres do not exceed three-quarters of an inch in length.

IV. THE COTTON MANUFACTURE

Great Britain imports and manufactures more raw cotton than all the other countries of the world together. The average yearly export of manufactured cotton goods, to say nothing of the home consumption, is upwards of £50,000,000 sterling; the imported raw cotton alone being valued at about £45,000,000.

Lancashire and Cheshire are the great centres of the cotton manufacture in England; in Scotland it is carried on chiefly round the banks of the Clyde.

When, nearly 300 years ago, the cotton manufacture was first introduced into this country, all the work was done by hand. It is now almost entirely accomplished by machinery and steam. Abundance of cheap coal is therefore an essential, and this is readily supplied by the coal-fields in the neighbourhood of these great centres.

Show some raw cotton, and a piece of calico. Let the piece of calico be pulled apart into separate threads. Show that the work of manufacture from the raw material resolves itself into two great processes—the short matted fibres of the raw cotton must be formed into lengths of yarn or thread; and the threads must be woven into cloth.

1. **Preparing the yarn.**—It is impossible to attempt to convey a notion of the intricate machinery by which the various processes are carried out. We must be content with trying to understand the broad principles on which they are worked.

Willowing.—*Call attention again to the thickly matted nature of the raw cotton.*

The first step towards making this tangled mass into yarn must be to draw out and separate the fibres. This is done in a machine called a **willow,** which is really a large box in which rollers fitted with iron spikes are made to revolve rapidly. The raw cotton is put into the box,

and the spikes, as they revolve, catch it up, and tear and loosen the fibres, and shake it free from dust and dirt.

2. **Carding.**—From the willow the loosened fibres are passed on to the carding machine, which consists of **brushes** or **cards** made of iron wire. **Carding** is only another word for **combing** or **brushing.**

The work of the carding machine is to brush out and lay straight and parallel the cotton fibres, just as a girl brushes out her long hair.

The carded cotton passes out from the machine, like a thin white film, and is called a **sliver.**

3. **Spinning.**—The slivers are first taken to another machine, in which they are gradually drawn out and slightly twisted, by a process called **roving,** time after time, until they are longer, stronger, and finer than they were; after which the actual work of spinning begins.

In the spinning machine the rove or loosely-twisted thread is lengthened and strengthened by being still further twisted, and it leaves the machine as **yarn** ready for the weaver.

The strong sewing-cotton mother uses is made of several yarns twisted together.

4. **The work of weaving.**—*Take a piece—say a yard—of common calico, showing the selvage on either side. Tell that this material was woven in one long piece, perhaps* 500 *or* 600 *yards in length, but the width of the piece is the same throughout, and is marked by the selvage* (*self-edge*).

Call attention to the parallel threads which run the whole length of the piece.

These are known to the weaver as the **warp.** They are arranged by stretching a number of rests or bobbins of yarn, side by side, between two yarn rollers, one in front, the other at the back of the **loom.** The warp when finally arranged tells the width of the intended piece.

Show on a picture.

Next call attention to the other parallel threads in the calico, those which cross the warp at right angles, i.e. *in the direction of the width of the piece. These are called the* **weft** *or* **woof.**

We cannot see these **woof** threads in the picture. They are not anywhere attached to the loom as the **warp** are.

Show a picture of the shuttle. Tell that it is simply a long reel pointed at each end. The **woof** *is wound on the* **shuttle**.

The first thing after seeing the **warp** arranged, and the **woof** wound on the shuttle, is to give the threads a dressing of size and starch to further strengthen them.

This done, the weaver takes his place in front of one of the **yarn-rollers**, which is called the **cloth-beam**, and begins the work.

Call attention once more to the crossing of the threads in the piece of calico—the woof passes under one thread and over the next, and so on continually; just as the threads run in the darned hole of a stocking.

So then the weaver has to pass the shuttle with its woof from side to side across the warp; and he must pass it over one thread and under the next, and so on.

Imagine the time it would take if he were compelled to pick up every alternate thread in this way.

It is done in a much more expeditious way. Before the weaving begins, all the alternate threads are attached to a frame called a **heddle**, in such a way that they can be raised or lowered at will. The weaver passes the shuttle from right to left over one set of the threads, and of course under the others; then these which were below are all raised by the **heddle**, and, when the **shuttle** returns, it passes under them, and over the other set, which were above it before; and so the work goes on. There is but one thread of the weft. This is returned backwards and forwards, and forms the **selvage** at the edges of the cloth.

Lesson XXIX

BONES AND JOINTS

I. Introduction

Open up the new subject by a brief recapitulation from the earlier lessons. Make the class tell what they have already learned of the bony skeleton of the human body, and of its adaptation to meet the requirements of various animals. We are now going to examine this bony skeleton more closely.

II. The Bones of the Head

Let the class describe the two distinct parts of the head—skull and face—and tell the purpose of each.

1. **The skull.**—The **skull** or **cranium** is formed of **eight flat plates of bone** joined together at their edges, so as to make a kind of box to lodge and protect the **brain.** There is a round hole in the base of this bony box through which the **spinal cord** passes into the **spinal canal** of the vertebral column.

2. **The face.**—There are no less than **fourteen** distinct bones to form the framework of the face. These bones provide hollows for the feeding organs (the teeth, mouth, and tongue), the organs of sight, and the organs of smell.

III. The Bones of the Trunk

1. **The vertebral column.**—The vertebral or spinal column is made up of **thirty-three** separate bones, called **vertebræ.**

Lead the class to describe the structure of these vertebræ, and the manner in which they are joined to each other by **pads of cartilage.**

There are **seven** vertebræ to form the neck; **twelve**

to form the back; **five** to form the loins; and **five** to form the haunch or sacrum.

The four vertebræ below these, although separate bones in the child, become united into one, which is called the **coccyx,** in the adult. In man they are very small indeed. In the lower animals they form the tail.

The five vertebræ of the **sacrum** are only separate bones in the child. They are united into one solid bone in the adult.

Vertebræ of the neck.—In man the seven topmost vertebræ form the neck, and this is the arrangement for all mammals.

Call a boy to the front, and make him nod his head up and down, and turn it from side to side.

Here we have two distinct movements of the head. Let us see how they are brought about.

The base of the skull rests upon the topmost vertebra, which is called the **atlas-bone.** The nodding of the head is accomplished by the skull moving to and fro on this bone. This we call a **hinge-joint.**

The second vertebra has on its upper side a **peg,** which fits into a hole in the atlas-bone. It is on this account called the **axis-bone.**

The turning of the head from side to side is brought about by the atlas-bone turning round on this peg, as on a pivot, and carrying the head round with it.

A joint of this kind is called a **pivot-joint.**

Lead the class to distinguish between these two kinds of joints. Illustrate the hinge-joint further by reference to the elbow, the knee, and the phalanges of the fingers.

Lead the children to think of such animals as the ox, the pig, the horse, the giraffe, the elephant—each of these have seven vertebræ to form the neck.

Compare the structure and habits of giraffe and elephant. Both are fitted to browse upon the tender young twigs and leaves of trees. The giraffe, by means of its long neck, simply nibbles its food where it grows upon the tree; the elephant tears it off from the tree with its long trunk.

Why should not the elephant have the long neck of the giraffe?

What is the purpose of the trunk?

Compare the seven neck vertebræ of the giraffe with the seven of the elephant, and think of the head of each animal—strength in the one case; length of reach in the other.

The pig roots in the earth and the mole tunnels underground. They have short thick necks—why not a long one?

In birds the number of vertebræ of the neck varies considerably; but there are always more than in mammals.

Let the class mention some birds with extremely long necks.

The wading birds live on fish and other water animals. Their tall stilt-like legs raise them high up out of the water, and render the long necks necessary.

Certain of the swimming birds—*e.g.* the swan, the goose, and others—find their food with their bills in the muddy bottom of the water, as they swim. Hence the great length of neck. There are no less than twenty-three separate vertebræ in the neck of the swan.

Snakes and fishes have no necks; the head is joined directly to the body.

Lead the class to tell what they have already learned of the structure of the tortoise family.

What is the name of the shell which covers the body?

Of what does it consist? It is made up of the vertebræ and the ribs all grown immovably together into a sort of plate or shield. It is an external skeleton.

But can the creature move its head? Yes.

What does that show, then? That there must be neck-bones, and that these neck-bones are not fixed immovably, like the other vertebræ.

Tell that this is exactly the arrangement. The whole of the neck vertebræ are free to move, and the head can be drawn in or thrust out of the shell, or turned easily in either direction.

2. **The ribs.**—There are twelve dorsal vertebræ or vertebræ of the back. These carry the twelve pairs of ribs

which curve round and form a protecting wall for the thorax or chest.

The first seven pairs pass completely round, and are attached to a flat bone in the front of the chest—**the sternum** or **breastbone.** These are known as **true ribs.**

Below these are three pairs, which are not joined directly to the breastbone. They are attached to the seventh pair and to each other by cartilage. These are called **false ribs.**

The remaining two pairs are not joined to any other bone in front, but are quite free. These are called **floating ribs.**

Explain that the number of dorsal vertebræ, and consequently the number of ribs, is not the same in all mammals as in man.

Most mammals have more than twelve. **The number in the elephant is twenty.**

Some animals, such as **snakes and fishes,** have a very great number indeed.

Lead the class to think of the enormous number of vertebræ and ribs in the snake family.

Let them describe how these creatures use their ribs, with their ball-and-socket joints, as their means of locomotion, in the absence of limbs.

Show that in the case of fishes it is the ribs which give the creature its double wedge-like form, so essential to its progress through the water.

Picture a bird in the act of flight, and a fish swimming in the water. In each case there is a similarity of form—a more or less lengthened body tapering in front and behind to enable it to cleave the element through which it moves.

Lastly take the frog. This is a creature with no encircling ribs; but the absence of ribs **is not an accident or a mistake.**

Who can remember why the frog has no ribs?

Lead the class to describe the breathing of the frog, and to tell that the ribs, which do so much in the work of breathing

in other animals, such as mammals and birds, are not wanted in an animal which breathes by sucking in and gulping down mouthfuls of air, and can even breathe through the pores of its skin.

IV. The Breastbone

Birds are built upon the same general plan as mammals, but they have their own peculiar modification to fit them for the life they have to live.

What is the name of the long, flat bone to which the ribs are attached in front? **The breastbone.**

The breastbone of a bird is very large compared with the rest of the skeleton. It is a broad, flat bone, and in most birds its central portion is developed into **a strong keel.**

Show one, if possible, or a picture of the skeleton of a bird. Compare with the keel of a ship.

What is the use of the keel in the ship? This keel-like ridge of the breastbone assists the bird in its swift passage through the air, or (if it be a swimming bird) in the water.

It also forms a strong point of attachment for the large muscles which move the wings.

The running birds—those that cannot fly—have no keel to their breastbone.

Lesson XXX

THE LIMBS OF ANIMALS—LOCOMOTION

Commence the new lesson by taking again the human body as the model; and with the aid of a good wall-sheet show the structure of the arm and leg.

Lead the class to describe the three parts in each—upper limb, fore-limb, and hand or foot as the case may be.

Make them compare the two limbs as to their form and movements; and especially the hand and the foot.

Let them see that there is a general resemblance between the upper arm and the thigh, the fore-arm and the leg, the wrist and the ankle, the hand and the foot.

Show in each case where the resemblance ends and the differences begin, and compare the modification with the kind of movement required, making the children point out the peculiar adaptability of the limbs and their extremities.

Call upon the class to describe the nature of the joints at the elbow and the knee, and between the phalanges of the fingers and toes.

We call them hinge-joints. They are capable of only one movement—**similar to that of a door on its hinges.**

Now let us look at the shoulder-joint.

Bring a boy to the front and call attention to the broad, flat shoulder-blade. The bone from a shoulder of mutton might be easily cleaned and prepared for illustration.

Call attention to the **hollow cup or socket.** *Explain that the great bone of the upper arm has* **a round knob or ball** *at its extremity which just fits into this cup.*

Show the advantage of such an arrangement in the freedom of movement it gives.

Put the boy through a few arm-practices.

We call this a **ball-and-socket joint.** The bones are held in their places by strong ligaments to prevent the ball from slipping out of the socket.

Our next business will be to examine the limbs of the various classes of mammals, and see how far they resemble those of man.

All mammals have two pairs of limbs, corresponding to the limbs of man.

What is the first great purpose of limbs? They supply the means of locomotion—moving about.

Now think. Most mammals **run and walk** on the ground, but there are others that **climb trees**; others that **burrow in the earth**; others that **fly in the air**; and others again that **swim in the water.**

Let us take these one by one, for their limbs must be specially adapted to their special mode of life.

1. **Climbing mammals.**—*Lead the class to tell that chief among those mammals that spend their lives in trees are the monkey family.*

Show, if possible, a picture of the skeleton of a monkey. Point out the similarity in structure to that of man.

There are the same bones, arranged in the same way, **except in the hand-feet.**

Show that a foot like ours would be a hindrance to the creature in its tree-climbing.

Make the class compare the thumb of the monkey with the great toe of a man; and show the advantage these four-handed animals get from this simple alteration.

In most of the monkey tribe the thumb is opposable like ours. (*Show what is meant.*)

There are some of the family, however, in which the thumb is placed side by side with the fingers, and not opposite to them. The animal in this case cannot use its hands for climbing, but makes its way by leaping from branch to branch.

Lead the children to tell of other animals that climb trees. The cat is not provided with hands, and yet she is a good climber.

How does she climb? Her long, sharp talons help her to take a firm hold upon the tree. The squirrel lives in the trees, and he climbs in the same way.

2. **Burrowing mammals.**—*Lead the class to think of the mole. Show a picture and, if possible, a prepared specimen, and call attention to the broad, shovel-like fore-paws.*

These are the digging implements.

Compare the great size of these paws with the body itself. Call attention to the shortness of the limbs. These are made for strength. The usual bones are all present, but they are short and thick. They are turned outwards. Why?

3. **Flying mammals.**—*Show a picture of the bat, and, if possible, another of the skeleton of the animal.*

Call attention to the bones of the arms. Point out the upper arm and the fore-arm.

What ought to come next? The hand.

Well just imagine the bones of the hand lengthened out until they are longer than any other bones in the body—longer than the body itself. This is exactly the arrangement in the bat's hand.

The fingers are drawn out and form the framework for a sort of wing. Between the fingers themselves, up to the very finger-nails, a thin skin or web is stretched to form the wing.

This is the creature's means of locomotion in the element in which it is meant to live and find its prey.

Its wing is simply an altered, outstretched hand.

4. **Swimming mammals.**—*Show next a picture of the seal or some other of the* **fin-walkers.**

Tell that in the short limbs of these animals all the usual bones are present. Those of the upper and fore-arm are short and strongly developed; but the bones of the fingers are long. They form the framework of a large hand.

This hand is the only part of the limb which actually passes out of the body. We call it a **fin or flipper.** The fingers are webbed.

Show the special adaptability of such limbs for a water-life, and tell of the awkwardness of the creature on land.

Its natural home is the water, and there it catches its prey. The hind limbs are usually turned backwards in a line with the body. They too end in broad, webbed flippers, which serve the purposes of a tail.

The whale family have no hind limbs. They have instead a very large tail-fin.

Point out on the picture the difference between this and the tail of a fish.

The fore-limbs are simply fins, very closely resembling those of a fish.

Make the class tell the purposes of the tail and fins respectively in locomotion.

5. **Running and walking mammals.**—*Show, if possible, a picture of the skeleton of a cat. Tell that the limbs contain exactly the same bones as the limbs of a man.*

That which we usually call the foot is not really the foot of the cat, but only part of the foot—**the toes.**

Trace the limb upwards to the next joint, and tell that this is really the heel of the long foot.

This animal walks on its toes only, with its heels raised above the ground.

Point out the elbow and knee joints in the fore and hind legs respectively.

This peculiarity of structure gives great elasticity of movement.

All this may be shown with a living specimen; and attention should be called to the soft, padded toes, with their sharp talons, usually drawn up into their sheath, but capable of being thrust out at will.

Tell of the stealthy, predatory nature of these animals, and show the object of the toe-walking, the pads, and the talons.

Cats and dogs and most members of their families walk on their toes in this way; but the bears plant the whole foot upon the ground at each step.

Remind the class too that the hoofed animals, such as the horse, rhinoceros, and elephant, as well as the cud-chewers, all walk on their toes, for the hoofs are simply the toes enclosed in a hard case.

Lesson XXXI

TEETH OF MAMMALS

I WANT you to think about our lessons on food and digestion. Where does the work of digestion begin? In the mouth.

What do we call that part of the work? **Mastication.**

It is for the purpose of masticating the food that we are provided with teeth. Teeth will form the subject of our lesson to-day, but we shall deal with the teeth of all the mammalia as well as with those of man.

Lead the children to tell that in all cases the teeth are set

firmly in the upper and lower jaws; **that it is the lower jaw only that moves**; *that they themselves can move the jaw sideways as well as up and down.*

We shall best understand the teeth of the various classes of mammals by first examining our own.

I. Human Teeth

You all know that your own teeth are of different shapes and sizes. This is not an accident. Each kind of tooth was designed for a special purpose.

Pick out a child with a good set of teeth, and use him by way of illustration.

1. **Incisors.**—*Point out the long, broad, flat teeth in front of the boy's upper and lower jaws—four in each.*

They have sharp, cutting edges. We use these teeth for biting through our food. How does a boy bite an apple or a slice of bread and butter?

From their sharp, cutting edges, these are sometimes called "**chisel-teeth.**" Their scientific name is "**incisors,**" which means "**cutting teeth.**"

2. **Canines.**—Next to the **incisors,** on either side, and in both jaws, is a long, rounded, conical tooth. There are four of them altogether.

Show them.

Some of you may keep a dog at home. If so, look in his mouth, and you will find that he has four teeth like these, but that they are very large, sharp, and prominent. We speak of these four conical teeth of ours as **canines** or **dog-teeth,** because they are like those of the dog. **Canis** is the Latin name for **dog.**

3. **Molars.**—Behind the canines, in each jaw, and on either side, are a number of large, square, broad-crowned teeth, different from both the **incisors** and the **canines.**

Show these. Point out the roughened, uneven nature of their working surfaces. **These teeth are meant for grinding purposes.**

We call them **molars**, from a Latin word signifying a

mill. They are the grinders; they form the mill for grinding the food.

The full number of molars for an adult is twenty; *i.e.* there are five on each side of both jaws. Boys and girls have not so many. The last of the molars do not make their appearance till adult age.

Show a tooth of some kind. Tell that the bulk of the substance of all teeth is a hard bony matter—**dentine**; *but the whole of that part which appears above the gum is covered with an exceedingly hard substance, known as* **enamel.**

Let these be pointed out in the specimen. We shall have to speak of them again.

Tell that in the various lower animals we shall meet with the same three kinds of teeth—**incisors, canines, molars**; *but that every animal is not provided with all three kinds. Each has just those teeth which are specially adapted to the food on which it lives.*

Hence, if we examine the teeth of an animal, we can always say for certain what food it eats; or, if we are told what the food of a particular animal is, we can always describe the kind of teeth it must have to masticate that food.

II. The Carnivora

The cat is the most familiar type of the flesh-eating animals.

Make the children mention some of its great relations—e.g. *the tiger, lion, leopard, hyæna.*

Show a good picture of the head of one of these, calling attention specially to the teeth.

Note the remarkable size, sharpness, and prominence of the four **canine** *teeth.*

Lead the class to tell that these teeth are specially designed to seize and hold the prey, and tear flesh.

There is very little work for the **incisors**, hence they are very small.

The surfaces of the molars are furnished with sharp

ridges, and these work against each other at every movement of the jaw, like the sharp edges of a pair of scissors.

Tell that the object of this arrangement is to cut through the flesh on which these animals feed, and which cannot be ground up as other food can.

Most of the members of the dog family, as well as the bears, although belonging to the carnivora, vary their flesh food with vegetable diet—the bears more than the dogs. Hence we find in these animals a remarkable modification of the molar teeth. The sharp, cutting ridges of the exclusively flesh-eating animals disappear, and give place to the ordinary roughened surface of the grinders; and the greater the mixture of food, the greater the modification. In the dogs only the two back molars are so modified; in most of the bears three or four are affected.

Tell that this modification in the teeth is accompanied by a change in the mode of moving the jaw.

Sideway movement is not wanted in the jaw of the true flesh-eaters. They have to cut through, not grind, their food; and the jaw simply moves up and down. As soon as the molars become real grinders, as they do in the bears, the jaw accommodates itself to them, by moving sideways as well as up and down.

Tell next of the various aquatic flesh-eaters, such as otters and seals, which have to catch their slimy, slippery prey in the water with their teeth.

Their canine teeth are specially adapted for seizing and holding; and their molars are furnished with saw-like crowns, for biting the body of their prey in pieces.

In the walrus, one of the family, the canines of the upper jaw are very largely developed, and form great tusks, often two feet long, which the animal uses as weapons of attack. It has neither canines nor incisors in the lower jaw.

III. INSECTIVORA

Lead the class to tell that most of the bats are insect-feeders, as well as those little animals that are usually placed in this order, such as shrews, hedgehogs, and moles.

The special feature about the teeth of all these is that the molars bristle with sharp points, specially fitted to crush the hard coverings of the beetles and other insects on which they feed.

The jaw has only an up-and-down movement.

It is a remarkable fact that those members of the bat family that live on fruits and not on insects have none of these sharp-pointed teeth; their molars are true grinders; and the jaw has the double movement.

IV. RODENTIA

Make the class tell the meaning of the name.

Show a good picture of one of these little animals—a rabbit, rat, or squirrel, calling special attention to the mouth. A living specimen would of course be better than a picture, and could no doubt be easily provided by one of the children.

In this order we find no canine teeth. The incisors are very largely developed, and there is a considerable space between them and the molars.

Let us examine the incisors first. To begin with, there are never more than two in each jaw. They have sharp, chisel-shaped, cutting edges, specially adapted for gnawing purposes; and the teeth never lose their sharpness. Let us see how this is.

What are the two substances of which teeth are made? Dentine and enamel.

One of these is much harder than the other; which is it? The enamel is harder than the dentine.

Tell that the front surface of these teeth is composed of enamel, the rest of dentine. The gnawing work of the animal wears away both substances, of course; but as dentine wears more rapidly than enamel, there is always a sharp edge of enamel left.

Tell that as these teeth are constantly wearing down, they would soon wear completely away unless some provision were made.

The provision is, that these teeth have no roots as other teeth have, and that they grow from below as quickly as they are worn away at their edges.

The molars too are deserving of notice. Instead of irregular projections, these teeth have a number of parallel ridges running cross-wise; and the jaw has not only a sideway movement, but a further peculiar movement backwards and forwards. This helps the molars to do their work by a sort of rasping process.

V. Ungulata

Tell the meaning of the name. Latin, **ungula = a hoof.**

This order includes **all the hoofed animals**—the horse, elephant, hippopotamus, and rhinoceros, as well as that large class known as **ruminants** or **cud-chewers.** As they are **exclusively vegetarians,** the canine teeth are either very small, or altogether wanting; but they all have **immense molars** for crushing their food.

Show a picture of one of the ruminants, and lead the class themselves to point out the special characteristics of foot and mouth.

What supplies the place of incisors in the upper jaw? How is this pad used? Which of these animals has incisors in both jaws? The camel. The dentition of the horse is chiefly remarkable for the wide space between the canines and molars. This space is known as **the bar.** The **bit of the bridle** is made to fit into it. The molars are largely developed, and are twenty-four in number; and there are **six incisors in each jaw.** The canines are very small indeed.

Two enormous tusks form the chief peculiarity in the elephant. These are **incisors**; but there are **no other teeth in front** of either jaw, and **no canines.**

The hippopotamus and the wild boar are also furnished with a pair of tusks, but these are **largely developed canine teeth.**

Lesson XXXII

THE SKIN

I. Structure

The skin, although merely a thin covering for the body, is in reality a very complex organ, both in its structure and functions. The anatomist can easily separate it into two distinct layers or skins, one underlying the other.

1. **The cuticle.**—The outermost or top skin is called the cuticle. It is a thin, horny, almost transparent layer, having neither blood-vessels nor nerves. It has, therefore, no sensibility to pain, and does not bleed if cut. It forms a protection to the more sensitive layer below.

Run a needle through the skin on the thick part of the hand, and show that it neither bleeds nor causes pain.

2. **The cutis.**—The true skin lies below the cuticle, and is known as the **cutis** or **dermis.**

As the cuticle lies **on** the dermis, it sometimes receives the name **epidermis—epi-dermis** meaning simply "**on the dermis.**"

The true skin is a closely interwoven mass of fibrous tissue, crossed and recrossed with blood-vessels and nerve fibrils.

Take a very fine needle, and prick the skin sufficiently to draw blood. The prick also causes a slight sharp pain.

Now what does this tell us? The blood-vessels form so close a network everywhere through the true skin, that it is impossible to prick it without piercing some of them, and causing blood to flow.

The fact of feeling pain from the prick proves that the nerve fibrils are as abundantly distributed.

Tell that these two layers lie naturally close to each other, and we cannot pinch up a fold of the skin without taking up

both. When, however, we scald or burn the skin, and a blister is formed, it is the cuticle only that rises.

The irritation of the burn has caused a watery fluid to exude from the under surface of the cuticle, and this fluid not being able to escape, forces asunder and separates the cuticle from the true skin below, and a blister is formed.

II. Function

What happens to our skin when we have been undergoing any violent exertion, or when we sit for some time in a very hot room? We see round drops of liquid on the skin.

We call this liquid "**sweat**" or "**perspiration.**" This sweat oozes out from the skin. We must find out what it is, and how and why it is thrown off by the skin in this way.

1. **The sweat glands.**—If a piece of the skin from any part of the body were examined under a microscope, it would be found to be pierced with a great number of tiny holes. These holes are the **pores** of the skin.

In the palm of the hand there are about 2500 on every square inch of the skin. There are from three to six millions of these pores on the entire surface of the body.

The pores are the openings of little tubes which extend inwards from the surface. They are about a quarter of an inch long, and the inner extremity is coiled up into a sort of ball. These are the perspiration or **sweat glands.**

Draw on the black-board a sketch of one of these coiled tubes, or show a good diagram of one.

*Tell that a "***gland***" is an organ whose business it is to be constantly at work separating or taking away certain fluids from the blood—some (like the sweat) to be thrown off from the system, as injurious, others to be used in the work of the body—e.g. the saliva or spittle, which is required in the work of digestion.*

If all the little tubes of the sweat-glands in your body

could be placed in a line, end to end, **they would extend from twenty-eight to thirty miles.** Every one of us, therefore, has in his own body nearly thirty miles of sewerage or drain pipes, for carrying off the impurities from the blood.

But how does this watery sweat with its impurities find its way from the blood into the sweat-tubes, and so to the surface of the skin.

Each little sweat-gland is closely enveloped with blood-vessels, and the walls of the blood-vessels, as well as those of the little tubes themselves, are so exceedingly thin, as to afford **an easy passage for fluids** through them **by osmosis.**

Repeat here, if necessary, the experiments illustrative of the process of osmosis, making the class explain what takes place. It has been already dealt with at some length.

In the true skin the blood-vessels are, as we have seen, set in an extremely close network everywhere. As the blood in these vessels moves along, its impurities are drained off into the sweat-gland, and sent upwards to the surface of the skin.

2. **The sweat regulates the heat of the body.**—One very important purpose of the perspiration is to preserve the proper temperature of the body, so that it may not suffer from too great heat, whether from within or without.

Tell that the healthy temperature of the body is from 98° *to* 100° *Fah., and it never rises above this except in cases of fever.*

Imagine a person overheated from within by violent exertion, or placed in a very high temperature. His skin at once begins to act vigorously, and the body is bathed in perspiration. This perspiration rapidly passes off from the surface of the skin in vapour, and in so doing carries away heat from the body, so that the natural temperature is still maintained.

III. Cleanliness

The many miles of drain-pipes have, as we have seen, most important work to perform, if the body is to be kept in a healthy state. It is in the highest degree necessary to assist them as much as possible in their work.

One of the best ways of assisting them is in keeping the body clean. People who neglect their bodies, by not frequently washing them all over, often become the prey of loathsome skin diseases and various disorders.

They allow the mouths of the glands to become clogged or choked up with dirt; and the poisonous waste-matters, having no proper outlet, remain there and create disease. **Therefore wash well and often.**

The skin should also be protected as far as possible from cold and damp.

Perspiration is always going on, although we cannot always see the drops of liquid on the skin.

This insensible perspiration must be allowed to go on without any check. Therefore every care should be taken not to check the action of the glands by exposing the body to damp and cold for any length of time.

Explain that this does not preclude the plentiful use of cold water on the skin. Never be afraid of cold water. A good rub down with a rough towel is all that is needed to set the body in a glow again after the bath.

Lesson XXXIII

THE COVERINGS OF ANIMALS

I. Introduction

Man is the only mammal, with the exception of the whale family, whose skin is naked, *i.e.* unprovided with a natural covering. But this does not show that other animals require a warm covering more than man. It is a proof of

man's superior intelligence. He is able to clothe himself, and to vary his clothing to suit the variations of climate.

In the lower animals Nature does it all. Every creature is provided with a covering of some sort to suit the conditions under which it is intended to live. Nature too provides for a change of clothing to suit the returning season.

Lead the class to tell of the difference in the thickness of the cat's coat in summer and winter, and why this is so.

We alluded to the whale as an exception to other mammals in this respect. It has a naked skin, **but beneath the skin is an under-coat,** so to speak, **of solid blubber or fat.** This fat wraps the animal at all points like a thick blanket, and he does not feel the icy cold of the polar seas in which he lives.

Make the class tell the nature of fat, and why it is able to keep the animal warm.

Why would not a thick woolly covering do as well?

Tell of the great bulky body that has to be propelled through the water, and show what an impediment to all movement an outer woolly coat would be.

The smooth, slippery skin glides easily along and facilitates locomotion.

Mammals have various coverings of hair, fur, or wool; but all of these are in reality the same substance. Fur and wool are only hair somewhat modified.

II. Structure of a Hair

Each hair consists of a root, a shaft, and a point. The root is bulbous in form, and is embedded in the true skin, where it is nourished with blood from numerous tiny blood-vessels. The little pit or hollow which holds the root of the hair is provided with a delicate lining called the **root-sheath.** This sheath closely envelops the bulb, and when a hair is pulled out by the root it tears away the sheath with it.

Pluck a hair from the head, and show this. If a microscope be at hand, so much the better.

The shaft or stem of the hair consists of a long conical fibre, and if examined by means of the microscope is seen to be made up of an outer layer of scales which seem to overlap each other like the tiles of a roof. Deeply embedded in the true skin, and opening at the side of each hair, is a little gland which has the power of separating from the blood a fatty or oily fluid to serve the purpose of a natural hair-oil in keeping the hair moist and supple. These are known as the **sebaceous glands.**

Tell of the oily, greasy feel of the wool on the sheep's back.

This is due to the oil from the **sebaceous glands,** which are very thickly spread in the skin of the animal.

III. Hair and its Uses

The hair of animals is not largely used in the manufacture of clothing fabrics. We import, however, for this purpose goat's hair from Turkey and South Africa; and hair or wool from the alpaca and llama of South America. The hair of all our domestic animals is made use of in many ways.

Horse-hair.—(*a*) The long hair of the tail and mane is spun into a coarse thread, and woven into a rough kind of cloth much used in the arts and manufactures.

(*b*) This is not the same kind of hair-cloth used for seating chairs, sofas, etc. In this the hairs are not twisted, and they run in one direction only of the fabric, the cross threads being strong flax or hempen yarn.

Some of the best of the hairs are used in making violin bows, and fishing lines, and also for sieves.

(*c*) The short hair which is not available for any of these purposes is used for stuffing chairs, sofas, mattresses.

Show some of the hair. Call attention to its curly, springy nature. It makes a comfortable seat.

Tell that in preparing the hair for this purpose it is first spun into a thick rope, and these ropes are then plaited and

twisted very tightly one in the other. In this state they are put into a slow oven and gently heated.

This treatment has the same effect as the heated curling-tongs of the hairdresser. It enables the hair to keep the curl that the twisting has given it; and it is the curly character of the hair that gives it its elasticity, and **makes it so suitable for stuffing purposes.**

The short hair which is removed from the skin of the horse and cow, in the process of leather-making, is used by builders for mixing with the mortar to make ceilings. The hair holds the mortar together, and helps to bind it to the laths which support it.

IV. Fur

1. **Its properties.**—In some animals the hairs are very fine, soft, and smooth, and grow thick and close. Such a covering is called fur.

The fur animals mostly belong to the colder regions of the earth—some of them to the extreme frozen north. Nature has provided the very coat that is best suited to such a climate.

Make the class tell that fur is a bad conductor of heat, and that, therefore, it will only allow the heat of the body to pass off slowly.

Tell that all these animals partly shed their fur in the summer, so that during the hot weather their coat is loose and open. When they take the cat or a rabbit in their arms in the summer, their clothes are soon covered with loose hairs. Before the return of winter the furry coat is renewed as thick and close as ever.

In some instances—*e.g.* some of the foxes of the Arctic regions, the hares of Scotland, and the stoat of our own country—**the fur changes colour at the approach of winter.** After a few days' exposure to the snow, the fur becomes white, not because new white hairs have grown, but because every existing hair has changed colour.

Make the class think again of their lessons on heat.

Lead them to tell that white and light-coloured substances generally are **bad radiators of heat,** *and that these white fur-coats do not radiate the bodily heat so quickly as darker ones would.*

Tell, too, that the whiteness of the fur being so like the snowy surroundings affords a protection to the animals from their enemies.

Have a cat or a rabbit at hand for examination by the class. Lead them to see that the hair of the coat is not all alike.

Point out the thick, close, short, silky hair nearest the skin. This is the real fur.

Now show the longer, stiffer, and straighter hairs that overlie this. These we call the **over-hair.**

Tell that these long, stiff hairs perform an important duty in helping to keep the fur somewhat loose, and so prevent it from matting together.

2. **Uses.**—The furs of animals furnish us with one of the richest, warmest, and most beautiful materials for our own clothing.

Many thousands of animals are killed every year for the sake of their "**pelts**"—*i.e.* the fur-skins.

Lead the children to tell, from what they have learnt, that winter is the time for taking these animals. Their fur is then thickest.

Most of the skins are dried and dressed with the fur on them, and so used. It is estimated that for this purpose alone no less than 30,000,000 pelts are collected every year.

Among the furs used are those of the squirrel, sable, hare, rabbit, ermine (the white winter-dress of the stoat), pole-cat, black fox, silver-fox, red fox, blue fox, beaver, seal, sea-otter, minx, bear, skunk, marten, and racoon.

Many of these owe their elegance and value chiefly to the length and fineness of the over-hair; but in the preparation of the seal-skin the over-hair is all cut away.

Immense numbers, amounting to many millions, of hare and rabbit skins are used every year in the manufacture of felt for felt hats.

Show an ordinary felt hat, and the children will see that for this purpose it is the fur only that is used, and not the skin also. The fur is first separated from the skin, and then by means of hot water and pressure the hairs are made to interlace and mat themselves together into a felt.

Lesson XXXIV

WOOL

I. Properties of Wool

Show some specimens of wool, and, if possible, a piece of the sheep's skin with the wool on it.

Make the class tell that wool, the natural covering of the sheep, is only a modification of common hair; that it has been used for making textile fabrics from very early ages; and that it is obtained from the animal by shearing during its life-time, and not only after death.

Have the specimens carefully examined, and lead the class to find out by observation the most striking properties.

Wool is white, and very wavy in appearance; it is light and flexible, and softer than ordinary hair; it is compressible, but very elastic.

Lead up next to its property as a non-conductor of heat, making the children compare the wool in this respect with some other fabric.

Why does it feel warm?

Warm a handkerchief in front of the fire, and let the children take it in their hands. Is this the same kind of warmth?

See, by reference to the former lessons, that the children have fully grasped this subject.

Show next a picture of some wool fibres highly magnified. Call attention to the rows of scales which may be seen covering the fibres and overlapping one another—something like the scales of a serpent's skin. At each bend in the wavy filaments the scales may been seen to project outwards.

Tell that the reason of this is that the scales are attached to the fibres on one side only, and wherever a bend occurs the free edges of the scales stand out from the hair itself.

This scaly nature of its fibres is one of the most important characteristics of wool. It is one which we have not met with before in any of the textile fabrics, for both linen and cotton have smooth fibres. The scales are not equally abundant in all wool.

Show some Saxony or fine Australian wool side by side with some specimens of the coarser English wool.

In the first the fibres are comparatively short and very wavy. **It is generally known as short-staple wool.**

A fibre of this under the microscope would show a profusion of scales. In some of the finest kinds there are no less than 2500 to the inch, and the fibres have the appearance of being serrated or saw-like.

In the English wool the fibres are longer, coarser, and less wavy; and it is generally described as **long-staple wool.**

Tell that the word **staple** *is a name given to each individual fibre. Hence* **long or short staple** *means simply* **long or short fibre.**

A fibre of long-staple wool would show under the microscope a much smaller number of scales and serrations than the short staple.

II. Uses

Its properties as a soft, light, flexible, non-conducting substance make wool a valuable material for clothing purposes.

It is made into a great variety of fabrics; but the particular kind of fabric depends entirely upon the profusion or otherwise of its scales.

Show again the picture of the magnified fibres. Imagine a number of such fibres crossing each other in opposite directions, and pressed close together.

What would happen? The projecting scales would catch one in the other and hold fast.

Show a piece of flannel and a piece of broadcloth.

Both are made of wool. The one we may easily separate thread by thread, and fibre by fibre; the other is a closely matted felt which it is very difficult to pull asunder.

Tell that the difference is entirely due to the scarcity of scaly projections in the one case and to their profusion in the other.

This one difference causes wool to yield to the manufacturer two distinct classes of products. The long-staple wool, with few projecting scales, yields flannels, blankets, moreens, merinos, alpacas, poplins, and all kinds of **worsted goods.**

The short-staple wool, with its abundance of projecting scales, is admirably adapted to felting purposes, and is made into broadcloth, kerseymere, and a great variety of materials known as **woollen goods.**

Tell that the name **worsted** *was given to that particular class of fabrics because they were first made at the little village of that name in Norfolk.*

III. Shearing the Wool

Lead the children to think of the sheep and its habits; it lives in the open air day and night, summer and winter.

Make them tell the peculiar fitness of this thick, light, porous, non-conducting coat of wool as a covering for such an animal.

What happens to the coat as winter comes on, and why?

What would happen to the coat on the return of warm weather?

Instead, then, of leaving the wool to fall out during the summer, the farmer cuts it off each spring.

Tell the way in which this is done. The sheep is first washed, then allowed to run about in sunny fields to dry; the shearer then cuts away the wool with a large pair of shears, commencing with the neck and under-parts of the body, and so on to the sides and back.

All the wool from one sheep is called a **fleece.** The wool from different parts of the fleece varies much in quality—that from the breast, neck, and back being the best; that from the hinder parts the least valuable.

IV. The Process of Manufacture

Show some wool in its raw or imported state. Let the class handle it, and tell that it is very greasy and very dirty.

Hence the first business in preparing it for the manufacturer is to thoroughly cleanse it.

Tell that this is done by boiling it in water with plenty of soap to dissolve and separate the grease and dirt.

When this is done, the wool is usually dyed the required colour, and then the fibres are torn asunder by means of revolving iron spikes until they form a loose, fluffy down.

Show a piece of some worsted material, and set the children to separate it into the threads of the warp and the woof, as they did in the cotton and linen fabrics.

Let them untwist these threads, and so show them that in the spinning and weaving processes the work is practically the same as that which they are already acquainted with.

There is one material difference after this in the treatment of the two sorts of wool.

The short-staple, wavy, serrated wool is sometimes known as **carding wool**; the long-staple as **combing wool.**

In the **combing** process the long, loose fibres are merely drawn out and arranged side by side as in the combing of cotton fibres.

In the **carding** of the short-staple wool, care is taken to arrange the fibres side by side in such a way that the ends of some point to the roots of others—that is, so that the teeth or serrations point in contrary directions.

The result of this arrangement is that when such threads are twisted to form yarn the serrations catch one in the other and prevent the thread from untwisting.

The spinning and weaving processes are the same for woollen as for worsted goods; but when a worsted fabric leaves the loom it is quite finished and ready for use. Not so the piece of cloth.

Compare once more the pieces of flannel and broadcloth: make the class tell the difference.

In the cloth the warp and woof threads are not to be seen, and the surface is a smooth, close, glossy nap.

Tell that this difference is brought about by the process of **fulling** *or* **felting**.

In this process the cloth is folded and beaten with large heavy hammers for many hours—even days; and this causes the fibres of the wool to felt or mat together, so that the cross threads of warp and woof are no longer visible, the little serrations on the fibres being the real cause of the felting.

Of course this folding and beating of the woven material causes it to thicken considerably and at the same time to shrink both in length and breadth.

After fulling, the nap of the cloth is raised in a curious way. A great number of the flower-heads (seed-vessels) of the teasel, a plant something like a thistle, are fixed to a large broad wheel, which is made to pass very rapidly over the cloth, so that the teasels sweep its surface continually.

The teasels are covered with little elastic hooks, and these, as they sweep over the cloth, catch up the loose fibres of the wool, and make them stand as a nap.

This raised nap is then made smooth and level by means of shears, after which all that remains to do is to damp, brush, and press it so as to give it the soft, smooth, glossy surface which is its chief characteristic.

STANDARD VI

STANDARD VI

LESSONS FROM MECHANICS

(BOYS ONLY)

Lesson I

MACHINES

I. The Forces of Nature

Introduce the lesson by setting a boy to move some heavy object—e.g. *a large box or a desk—along the floor. If one boy cannot do it, let two try. As the desk is being propelled along, let some other boys first change the direction of its movement, and then stop it altogether by pushing in other directions.*

Call attention to the fact that the boys, in order to do all this, had to make an effort to put out their strength.

Whenever we lift a heavy weight, whenever we set a body in motion, whenever we stop a body that is already in motion, we are conscious of exerting some effort. The name given to this effort is **force.**

Force is any cause which tends to move a body, to change the direction of its movement, or to arrest it when in motion.

The force which the boys used was their bodily strength. We call this **muscular force.**

Man, in his primitive state, learned first to use this muscular force. In fact, the only force he employed was the muscular force of himself and the animals he subdued. Savage nations of to-day know very little of any other force but this.

But the civilised man gradually learned, and is learning still, that there are many wonderful forces existing around him; and his own ingenuity teaches him how to utilise them.

His observation soon taught him that **wind** is a force, and after a time he learned to turn this force to account in various ways.

Make the class mention some of the ways in which man employs wind as an agent of motion.

Things floating down a stream suggested to him the force of **running water,** and this became, through his ingenuity, another powerful working agent.

In fact, science has taught man gradually to utilise these and other forces, such as gravity, cohesion, heat, steam, chemical force, electricity.

We group them all under the name of natural forces.

II. How we utilise them

When the boy moved the heavy box by the exertion of his muscular force, we might have noticed three things.

1. That he applied the force to a particular part of the box.
2. That he pushed in a certain direction.
3. That when his own force was insufficient, he increased it by the help of another boy, and so did the work.

In all our attempts to utilise a force these same three things must be considered—

(1) Its point of application, *i.e.* the portion of matter on which it acts; (2) its direction; (3) its intensity or magnitude.

In almost every instance a force can only be turned to

account, after we have altered it, in one or other, or all of these particulars, to suit our requirements.

Lead the class to think of a wind-mill and a water-mill. Show drawings of both in section. The essential part in each is the great mill-stone, which has to be set in motion. The force which is to accomplish this work is, in one case the wind, in the other the running water. The wind-force acts on the sails; the water-force on the large wheel. The mill-stone cannot, in either case, move till the force is transmitted to itself.

Notice too the change in direction. The sails and the wheel revolve vertically; the mill-stone horizontally.

The whole contrivance of the mill is to effect these changes in the force, and so render it available for the purpose of grinding corn.

Any contrivance for transmitting a force from one point to another, or for altering the direction of movement, is a machine.

Let us take another example.

A workman wants to raise a basket of bricks or a pail of mortar from the ground to the scaffold at the top of the building where he is working. He does not wish to descend and remount the ladder, so he lowers a rope. One end of this is hooked on to the basket, and he raises the weight by his own muscular force.

This force is actually applied at the upper end of the rope, but the rope transmits the force to the basket.

Hence the rope is a machine. It changes the point of application from the upper end of the rope to the basket at the bottom.

Call attention to the fact that the man raises the basket by exerting a direct **upward force,** *greater than the force of gravity caused by its weight, which tends to pull it downwards.*

Now show a fixed pulley. Let the children examine it, without troubling for the present as to its proper name or description.

It is simply a wheel with a hollow, grooved circumference, round which a cord passes.

To each end of the cord attach a pound weight, and let the

class note the result. **The weights balance each other on either side.**

Now hang a small weight (say half an ounce) on one side.

What happens? That and the pound weight together overcome the one on the other side—they fall, and it rises.

Now let the class imagine such a wheel fixed to the workman's scaffold.

Two baskets of bricks, both pulling downwards by the force of gravity, would balance each other; but one brick more in either basket would cause it to sink and the other to rise.

Suppose the man were to unhook one of the baskets; how could he manage to keep the other in its original position? By pulling downwards, just as the basket did, and with the same force.

And if he pulled a little harder what would happen? The basket on the other side would rise.

That is to say, the man by pulling the cord downwards over the wheel, exerts an upward force on the basket at its opposite end, and causes it to rise.

The wheel and the cord constitute a machine.

They change the point of application, and they alter the direction of the force.

Workmen usually employ this means of raising their materials to the scaffold, because it is easier to pull downwards than it is to lift the entire weight upwards.

It often happens that the men have to raise heavy masses of material (such as great sheets of lead, or coils of leaden pipe), which it would be impossible for them to lift from the ground with only their own muscular force. We will see how they do it. Let us return to our wheel and cord.

Take one end of the cord as it hangs over the fixed wheel, and pass it round and under a similar loose wheel, hooking the end of the cord to the beam above. Here we nave a contrivance consisting of a fixed and a movable wheel, with the same cord passing round both Pull at the other extremity of the cord,

and show that the second wheel actually moves up as the cord is pulled down.

Now hook a 2-lb. weight to the movable wheel, and a 1-lb. weight to the free end of the cord. What happens? The two weights balance each other.

It would be just the same if we used 4 lbs. and 2 lbs.; 100 lbs. and 50 lbs.—they would balance.

N.B.—*The weight of the pulleys is disregarded here in order to avoid complications. The teacher by some little contrivance with the respective weights might arrange for this.*

Now hang the slightest additional weight to the end of the cord, and the movable pulley with its heavy load rises.

This is the kind of contrivance used for raising heavy weights. With such a contrivance fixed to the scaffold, men are enabled, by pulling downwards at the end of the cord, to raise a heavy mass of material which they could not possibly lift without help.

Such a contrivance is a machine.

The men apply the force at one end of the rope; it is transmitted to the other. The force is applied downwards; the heavy mass is raised upwards. The small force exerted by the man is increased in magnitude or intensity, so that it is enabled to raise a much heavier weight than it could without such a contrivance.

Lesson II

THE LEVER

I. Introduction

We employ a vast number of machines to do an almost endless variety of work. Some of them are very complicated.

But however complicated they may appear to be, they are all found on examination to be made up of a few simple contrivances which have been invented for the

purpose of altering force in one or more of the ways we mentioned in last lesson.

These contrivances, or simple machines, can be grouped under six heads, and are spoken of as the **mechanical powers.** They are the **lever,** the **wheel and axle,** the **pulley,** the **inclined plane,** the **wedge,** and the **screw.** The lever, the pulley, and the inclined plane are the simplest of all, and are known as **primary machines.** The others are modifications of these, and are designated **secondary machines.**

In all these machines the force used is named the **power**; and the body to be moved is called the **weight** or the **resistance.**

We will commence with the lever.

Set a boy to lift some heavy piece of furniture, e.g. *a heavy box, a cupboard, the master's desk. He cannot do it. The resistance offered to his muscular force by the weight of the body is too great.*

Now show an ordinary iron crow-bar. Tell him how to use it, and show him that by exerting a comparatively small muscular force at one end of the bar he can raise the heavy body, which he was powerless to move without it.

Lead the class to tell, from what they have been taught, **that the iron bar is a machine.**

The force applied at one end of it, downwards, is transmitted to the other end, and acts in an upward direction on the body to be raised. The small force applied by the boy is converted, moreover, by this bar into a force sufficient to lift the heavy body.

This altering of the force is just what all mechanical contrivances are meant to do.

The bar is the simplest of all machines. We call it a **lever.** All that is necessary in it is that it should be quite rigid, and unbending.

Show that a cane or a bar of any yielding material could never serve the purpose of a lever, because the force applied at one end, instead of being transmitted to the other, would be used up in bending the cane itself.

The lever, from its simplicity, was in all probability the first of man's inventions in the mechanical powers. We must now learn the principles on which the lever works.

II. How the Lever works

The principle of the lever may be practically illustrated by a very simple contrivance, the only thing wanted being a stout, flat lath of some kind, about a yard in length. A blind-stick, such as is slipped into the bottom of a holland blind, would serve the purpose very well.

Find the exact centre of the bar, and through this point drill a hole with a gimlet. At exact distances, say 4 inches right and left of this hole, bore other holes 1, 2, 3, 4, 5, 6, *as in the figure.*

The edge of the table, or some such firm object, will serve as a support or stand, and our contrivance is complete.

Drill a hole with the gimlet in the edge of the table, and a stout French nail or a screw will hold the bar in its place there.

With this simple contrivance the class may be easily led to find out for themselves the whole principle underlying the work of the lever.

Commence by placing the bar in different positions, i.e. *fitting the nail through several holes in succession.*

Show that in each case the bar is free to move on the nail.

This is the other essential point in a lever. It must be a rigid bar, and it must be capable of moving about a fixed point.

This point is called the fulcrum of the lever. The nail, then, is the fulcrum in our contrivance.

The parts of the lever on either side of the fulcrum are called the **arms.**

Now place the nail through the middle hole of the bar. The arms are now of equal length.

Hang equal weights at the end of each arm. What happens? They balance.

Now remove the weight from one end, and let a boy come to the front and balance the bar as before.

How does he manage to keep the balance? By pressing down on the end of the bar.

With what force must he press? With exactly the force of the weight he removed, which was the same as that at the other end.

That is to say, the two weights at first balanced because they were both pulling downwards with equal force at the two ends of the bar; and **the boy must exert an equal amount of muscular force downwards** at the one end to balance the weight hanging at the other.

The smallest amount of additional force used now would enable the boy to raise the weight at the other end.

The force which the boy exerts is called the **power**; the body, whatever it may be, at the other end is called the **weight** or the **resistance.**

In the same way the two arms are known as the **power-arm** and the **weight-arm.**

Now alter the position of the lever, so as to make one arm twice the length of the other. Hang a weight on the short arm, and let the children find out by experiment that, to balance it, they must put one only half as heavy at the end of the long arm.

That is, if a 2-lb. weight be attached to the short arm, a 1-lb. weight will balance it at the end of the long arm.

Lead them to tell, too, that the boy by pressing on the end of the long arm (power-arm) would need to exert a force of 1 *lb. only to balance the* 2 *lbs. at the end of the* **weight-arm.**

Follow on next, in this way, with various rearrangements of the lever, making the **power-arm** *in turn* 3, 4, 5, 6 *times as long as the* **weight-arm.**

Keeping the 1 *lb. at the end of the* **power-arm,** *lead the children to find out for themselves that that is sufficient, in the various positions, to balance* 3, 4, 5, 6 *lbs. respectively.*

The boy too with the lever in the last position uses

very little exertion at the end of the **power-arm.** He presses downwards with only the force of 1 lb. to balance the 6-lb. weight at the end of the weight-arm.

Here we have a machine which gives us a distinct advantage. When we used the lever with equal arms, the only advantage gained was in changing the direction of the force. To raise the weight, the power pressed downwards instead of upwards. This, as we have already seen, is easier.

With the power-arm longer than the weight-arm, a small force will raise a heavy weight; and the longer the power-arm is, as compared with the weight-arm, the greater will be the weight which that small force can raise.

Set out on the black-board the relationship existing between the power-arm and the weight-arm, the weight and the power in each position in which we placed the lever.

Tell that in all levers the same relationship exists.

We can calculate easily the **weight** which any force is capable of raising by means of a lever, if we know also the respective lengths of the two arms of the lever.

The power multiplied by the length of the power-arm is always the same as the weight multiplied by the length of the weight-arm.

The shorter the weight-arm, therefore, the greater must be the weight; and the longer the power-arm, the smaller the power.

Notice that in each case **the fulcrum has been between the power and the weight.**

This is always so in the **first order of levers,** such as we are studying.

III. Practical Applications of the First Order of Levers

1. A see-saw.

Make the class tell that the child at each end becomes in turn the power and the weight. How do they act when one boy is heavier than the other? Why?

2. The poker in the act of stirring a fire; and the crow-bar in raising a flag-stone.
3. The claw-hammer in drawing a nail.
4. A common pump-handle.
5. A pair of scales for weighing goods.
6. A steelyard for weighing goods.
7. The spade in digging.

As far as it is possible, all these illustrations should be dealt with in a practical way. The children should be made to find out for themselves fulcrum, power, and resistance in each case.

Compare the scales with the steelyard. In the one we use a great number of weights; in the other we have only one weight. Why?

8. A pair of scissors, pincers, and nippers are examples of double levers of the first order.

Show the position of fulcrum, power, and resistance here.

Why do we bring hard, stiff material as close as possible to the rivet of the scissors when we wish to cut it?

Lesson III

THE LEVER

I. Second Order of Levers

Commence by making the class tell the distinguishing feature of the first order of levers. The fulcrum is always between the power and the weight.

We are now going to consider a lever of another kind, in which we shall find **the fulcrum at one end.**

We shall alter our model by merely putting the peg through the hole nearest the end of the bar.

Hang a 1-lb. weight at the other extremity, and call a boy to the front to hold the bar in the horizontal position. He finds it requires some exertion. He is pulling upwards. Still we cannot tell what force he is exerting. Let us try and find out.

To the same hole in the bar to which the weight is attached fasten a cord; pass the cord over a small fixed pulley placed immediately above it; and at the end of the cord hang another 1-*lb. weight. The boy may let go now,*[1] *and the bar lever will remain horizontal, held in its place by the* 1-*lb. weight at the end of the cord.*

The class ought to be able, from what they have already been taught, to tell why we employ the pulley. The cord pulls downwards on one side with exactly the same force as it pulls upwards on the other side.

We had at first no means of telling the upward force, but we know now that it was a force of 1 lb.

What have we learned from this? That the **weight** of 1 lb. at the end of the lever is supported by a **power** of 1 lb. acting also at the end of the lever.

This is just as we might have expected from what we already know. The weight-arm and the power-arm are the same length; hence the weight and the power must be equal.

Now, without interfering at all with the cords, let a boy remove the 1-*lb. weight from the end of the bar, and place it midway between the end and the fulcrum.*

Does the lever assume the horizontal position now, when left to itself; *i.e.* do the two forces balance? No.

Lead the children to find out for themselves, by experiment, that to get a balance now we must suspend a 2-*lb. weight from the middle of the lever.*

What does this mean?

Tell that the cord, which we may call the power, is still pulling upwards at the end of the lever with a force of 1 *lb. The weight pulling downwards is acting at the middle of the bar,* i.e. *at only half the distance from the fulcrum.*

The power-arm is twice as long as the weight-arm. Hence, from what we already know, we are not surprised to find that the weight is twice as great as the power.

[1] We are, as in the former lesson, disregarding entirely the weight of the lever itself. This, of course, must be taken into account and provided for by the teacher, who can explain later.

Continue the experiments, making the **power-arm** (i.e. *the whole length of the lever) in turn* 3, 4, 5, *and* 6 *times as great as the weight-arm. That is to say, place the weight at* $\frac{1}{3}$, $\frac{1}{4}$, $\frac{1}{5}$, *and* $\frac{1}{6}$ *of the distance between the fulcrum and the end of the bar.*

Lead the children to find out for themselves, by experiment, that the weights suspended at these several positions must be 3, 4, 5, *and* 6 *lbs. respectively.*

That is to say, the power of 1 lb. acting upwards at the end of the lever will balance the downward pressure of 3, 4, 5, and 6 lb. weights acting at these distances from the fulcrum.

Show that this is only repeating what we said about the first order of levers, except that in this case we have the power-arm and the weight-arm on the same side of the fulcrum.

In the second order of levers the power always acts at one end, the fulcrum being at the other, and the weight between them.

The longer the power-arm is, as compared with the weight-arm, the greater will be the weight which a given power can raise.

The power multiplied by the length of the power-arm is always the same as the weight multiplied by the length of the weight-arm.

II. Advantage of this Kind of Lever

In this second order of levers the weight is always nearer to the fulcrum than the power can be, for the power acts at the opposite extremity of the bar. Hence the mechanical advantage gained by such a machine is **an increase of power.**

We have seen too that the same bar may be used as a lever of the **second order** and of the **first.**

When such a bar is used as a lever of the second order, any given power acting at its extremity will raise a greater weight than if it were used as a lever of the first order.

Now let us for a moment go back to the levers of the first order.

Take two boys, a big and a little one, on a see-saw.

The little boy, as you know, sits on the long arm, the big boy on the short arm; and each becomes, in turn, the power and the weight.

When the big boy on the short arm is down, he is the weight, and the little boy sitting on the long arm becomes the power to raise him.

The little boy represents a very small power; but when that power acts at the end of the long arm, **it increases,** and he is able to raise the bigger boy.

When it becomes the turn of the big boy to act as power, the power is considerably greater than the weight to be raised, because it is acting at the short arm of the lever.

Now consider for a moment. Which boy has the best ride? The little boy. His end of the see-saw rises higher, and moves more quickly than the other end.

Now I think you will be able to understand what I am going to say further.

When the power acts at the end of the long arm, it increases in magnitude; but the weight to be moved moves slowly, and through a short distance.

When the power acts at the end of the short arm, the weight moves through a greater space, and at a greater speed, but there is a loss of power. It takes a great power to raise a little weight.

Gain in power must mean a loss in speed; and gain in speed must mean a loss in power.

Now if we apply this to our lever of the second order, we shall see that, with the power acting at the end of the long arm, we get necessarily a loss in speed—the weight does not move so far, nor so quickly.

The mechanical advantage therefore of levers of the second order is gain of power; and this, as we have seen, means loss of speed.

III. Practical Applications of the Second Order of Levers

1. **The crow-bar,** in the act of raising a heavy stone, using the ground as its fulcrum, becomes a lever of the second order.

Lead the class to tell that the weight of the stone rests on the bar between the power and the fulcrum, and that the man applies the power by forcing the lever upwards at the opposite end.

2. **A wheel-barrow.**—*Have an actual wheel-barrow before the class; and make the boys point out the position of fulcrum, weight, and power.*

3. **A boatman's oar.**—*Show a picture of a man rowing. Help the class to tell that the water is the fulcrum, the boat itself the weight, and the man who is rowing applies the power at the handles of the oar.*

4. **A chopping knife.**—*If an actual knife cannot be obtained, show a picture of one. Point out that the knife is fixed at one end. This forms the fulcrum. The person who uses it applies the power at the opposite handle; and the bread or sugar or meat (or whatever has to be chopped up) constitutes the weight or resistance.*

5. **Nut-crackers.**—*Show a pair of nut-crackers. The nut to be cracked is placed between the power and the fulcrum. These form a double lever of the second order.*

Lesson IV

THE LEVER

I. Third Order of Levers

Refresh the memory with a few questions dealing with the kinds of levers which we have already considered, and then push on to the new work.

There is still another kind of lever calling for our

attention. We will illustrate its use, as before, with the help of our model. It differs in its arrangement from both the others.

We shall speak of it as a **lever of the third order.**

We will arrange the model, so far as its fulcrum is concerned, in exactly the same way as in the second kind of lever; that is to say, we will place the **fulcrum at one end.**

The difference will be in the relative positions of the **power** and the **weight. In the third order of levers the weight is always at the end opposite the fulcrum,** and the **power between the two.**

Now, as before, let us hang our 1-lb. weight at the end of the lever, and through the middle hole in the bar pass the cord which is to run over the pulley. This cord shall represent, as it did in the last lesson, the power; it will act just half-way between the fulcrum and the weight.

Let a boy come to the front and keep the lever balanced in a horizontal position, by pulling the end of the cord downwards.

What is the weight he is holding up?[1] The weight of 1 lb. hanging at the end of the lever.

Now let us see what power, acting at the middle of the lever, can balance the 1-lb. weight at the end.

Let the boys find out by experiment, first, that 1 *lb. will not balance it, that it requires more; and secondly, that at that particular point it requires a power of* 2 *lbs. to balance a weight of* 1 *lb. at the end.*

Can any one tell why? The weight-arm is twice as long as the power-arm, therefore the power must be twice as great as the weight.

Remove the cord, for further experiments, from the middle hole in the lever, placing it, in turn, $\frac{1}{3}$, $\frac{1}{4}$, $\frac{1}{6}$, *and* $\frac{1}{8}$ *of the distance between the fulcrum and the weight.*

Make the boys find out for themselves that, in these new positions, the 2*-lb. is unable to balance the lever with the* 1*-lb. weight at its end.*

When acting at $\frac{1}{3}$ the length, the force pulling at the

[1] That is again disregarding the weight of the lever itself.

cord must be 3 lbs.; when at $\frac{1}{4}$ the length it must be 4 lbs.; at $\frac{1}{5}$ the length 5 lbs.; and at $\frac{1}{6}$ the length 6 lbs., to balance in each case the 1-lb. weight at the end.

II. Mechanical Advantage of this Lever

It is now clear that, in levers of the third order, the power, being nearer the fulcrum than the weight, must always be greater than the weight. That is to say, it takes a great power to raise a small weight: **there is a loss of power.**

But we have already learned that **a loss of power means a gain of speed.** Let us see whether this is so in the present case.

Place a very small additional weight at the end of the cord, and leave the model to take its own course. The weight at the end of the lever is carried through a greater space, and at a greater rate of speed than the power.

The distance and speed of the power may be seen by noting the fall of the weight at the end of the cord. Hence in levers of the third kind there is no gain, **but a loss of power; but the advantage is a gain of speed.**

III. Practical Applications of the Third Order of Levers

The fact that levers of the third kind give no gain in power will explain why they are not so commonly used as others.

1. A shovel in the hands of a man shovelling up coals, sand, or corn, will give a good illustration of this kind of lever. The handle held in one hand becomes the fulcrum; the coal, sand, or corn lifted is the weight; and the power is applied, by the other hand, to some point in the shaft, between the weight and the fulcrum.

The man gains nothing in power—he actually loses

power, for the force he expends is greater than the weight he lifts.

When the weight is greater than usual, he shifts his power-hand lower down—nearer the weight. Why?

What he loses in power, however, he gains in speed. The heap of coals is rapidly moved.

A man with a pitch-fork and a load of manure, hay, or straw, is, of course, a similar illustration.

2. The treadle of a sewing-machine, a harmonium, a grindstone, or a lathe, are simple illustrations of this kind of lever.

Make the boys point out the position of fulcrum, power, and weight in these. **There is no gain of power.** *The person using the machine expends greater force than is represented by the weight lifted.*

Be sure the class form a clear notion of what the weight really is in each case. Show, if possible, one of these; if not, a good picture of one.

Take the sewing-machine. Call attention to the crank, at the farther end of the treadle, which connects it with the rest of the machine.

Compare the slight motion of the foot on the treadle with the greater and more extended motion of this crank at the back, and so of the wheels which fly round. **There is a gain of speed.**

3. A man raising a long ladder with the lower end pressed close up to the wall is a good illustration of the third class of levers.

Let the class give the positions of fulcrum, power, and weight. Show that the ladder, during the first part of the movement, really represents a lever of the second class—the weight lies between the fulcrum and the power. As it rises it becomes a lever of the third class, for the power then acts between the fulcrum and the weight.

4. The fore-arm raised upon the upper arm at the elbow gives a simple example of a lever of the third kind. The elbow is the fulcrum; the hand and whatever is in it is the weight; and the power is applied by the biceps

muscle of the upper arm to the bones of the lower arm below the elbow.

5. A pair of tongs raising a lump of coal gives a familiar example of a double lever of the third kind. The joint, where the two parts are riveted together, forms the fulcrum; the lump of coal raised is the weight; and the power is applied between the two.

Let a boy try to crack a nut with the tongs, and show him what a loss of power there is with this machine, as compared with a similar lever of the second order (nut-crackers).

Compare, however, the sweeping motion made by the ends of the tongs with that made by the power, and point out again that loss of power means gain of speed.

Lesson V

THE PULLEY

I. Introduction

Commence by leading the boys to think over the work that can be accomplished by the lever.

A mass of stone or some other heavy body has to be moved. A lever will move it; but only a few inches.

Picture a workman on the scaffold requiring a block of stone for the wall which he is building. There the block lies on the ground; but how is he to raise it? If he tried the lever, he would only succeed in raising it a little way; then he would have to prop it up in that position, take another fulcrum, and raise it a little higher. All this would have to be repeated again and again, many times, and with a tremendous expenditure of force, in order to raise the stone to the required position.

Or he might fix his lever and its fulcrum on the scaffold itself, and connect one end of it, by means of a rope or a chain, with the block of stone below. The rope or the chain, as we have already seen, will transmit to one end any force which is applied to it at the other. The man by applying force to the lever at the

top would thus be enabled to raise the block a short distance, when it could be propped up, and lifted in the same way a little higher, and so on.

But all this would be exceedingly tedious, and wasteful as regards the expenditure of force.

Now let us see how this use of the lever first suggested the idea of another machine—the pulley.

Take a short bar, similar to the one we have previously used, but about a foot in length; drill a hole through its centre, and fix it to the table-edge as before, leaving it free to rotate on the nail or screw.

The nail thus becomes the fulcrum, and the bar is a lever of the first order, with equal arms.

Now attach a cord to the end of each arm; at the extremity of one cord hang a weight of some kind, and let one of the boys pull the other cord down.

As he pulls the one arm of the lever down, he raises the other on the fulcrum, and with it the cord and the weight attached to it.

But how far can he raise it? He can only bring the lever into a vertical position, and so raise the weight a short distance; beyond that it will not move.

II. The Fixed Pulley

Now suppose that instead of a single lever we employ several, all of the same length, and so arranged as to cross each other at the same point—the same fulcrum. Such an arrangement of levers will resemble the spokes of a wheel.

A contrivance of this kind might be readily made with very trifling expense. The nave and spokes of a small wheel with the rim removed would do admirably. Have a groove cut for the cord in the extremities of the spokes. Fix the wheel on the table-edge or any other convenient place by means of the nail or the screw through its centre, leaving it free to move as before. The weight may now be attached to one end of the cord, and the boy

will easily raise it by pulling at the other. Each spoke in turn takes its share of the work, acting as a separate lever.

Now take a circular wooden disc having a groove round the circumference. On the disc mark very plainly a number of diameters, to represent as many levers, all crossing at the centre.

Fix the disc to the stand by means of a screw through its centre, just as before, leaving it free to revolve.

Pass a cord round the grooved circumference, and to one end of the cord attach the weight which is to be raised.

If a boy be now set to pull at the other extremity of the cord, the principle of action will be made quite clear. This revolving wheel is nothing but a succession of levers of the first order.

The weight at one end of the rope is raised by the person pulling at the other end. **Hence we call the machine a pulley; and because it is fixed on a kind of pivot at its centre, it is called a fixed pulley.**

III. Advantage of the Fixed Pulley

Let us think again for a moment, not of the wheel itself, but of any one of its imaginary levers. These are all of the same length; they are diameters of the same circle. Each one has two equal arms.

Now, if I wish to raise a stone weighing 50 lbs. with a lever of the first order, having equal arms, what force must I use? The force or power must be equal to the weight (*i.e.* 50 lbs.), because the arms of the lever are equal.

Then does such a lever give no advantage? The advantage is in the direction of the power. To raise the weight we apply the power downwards instead of lifting.

What is true of the single lever ought to be true of a number, and hence of the pulley. We have seen that it is so in direction. Let us see whether it is also true with regard to the force required.

Hang equal weights at the extremities of the cord, and show that they balance. The smallest addition made to either will cause the other to rise.

Notice now that there is a strain or tightness about the cords. They are being pulled downwards by the weights attached to them. Hence the greater the weight the greater the tightness. **We call this strain or tightness the tension of the cord.**

IV. The Movable Pulley

Show now a common block-pulley, fitted with a hook for holding a weight.

Pass a cord round the pulley, and fasten one end of it to a beam or some convenient stand in front of the class. Hang a 4-lb. weight to the pulley, and let a boy, mounted on the table if necessary, support it by holding the end of the cord.

Set him now to pull the cord upwards. What happens?

The block rises and carries with it the weight which is attached to it.

This pulley, instead of being a fixture like the other, moves upwards when force is applied to the cord. **We call it a movable pulley.**

Instruct the boy now to keep the two parts of the cord parallel, while we examine it further.

Now the entire weight supported by the block is 4 lbs. The block, that is to say, is being pulled downwards with a force of 4 lbs., the force of gravity due to the weight of the body itself. This weight of 4 lbs. is supported by two cords.

Therefore, what should be the **strain** or **tension** on each part of the cord? Each part of the cord ought to bear a strain or tension of 2 lbs.

That is to say, the boy ought to support the weight of 4 lbs. by applying a force of 2 lbs.

If this be true, the movable pulley is a distinct mechanical advantage as far as power and weight are concerned. Any given power will raise a weight of twice its value.

But what have we to say about direction? There is no advantage in direction, for the power is applied upwards.

The single movable pulley gives us no means of testing the truth of our statement with respect to the tension in the cord.

Pass the end of the cord over the fixed pulley, in such a way as to still keep both parts of the cord parallel, and let the boy test it for himself and the class by attaching to it a 2-lb. weight.

The result is proof at once. The 2-lb. force at the end of the cord balances the 4 lbs. hanging from the block.

We know that the fixed pulley gives no advantage in power. The tension of the cord on both sides of it is the same. Hence, whatever is the tension in that part leading from the movable to the fixed pulley, it is the same on the other side.

We see that to be 2 lbs. Hence we can prove that the advantage gained by a movable pulley is an equal division of the weight between the two parts of the cord.

What is the gain in using the fixed pulley with the movable pulley? The advantage is in change of direction. The force is applied downwards to the cord which passes over the fixed pulley.

Notice, lastly, that the distance through which the **power** end of the cord moves is twice that through which the **weight** moves; or, in other words, the weight moves at only half the speed and through half the distance travelled by the power. **We see once more that gain in power means loss in speed.**

As it is the principle of the machine which concerns us here rather than the various developments of it, there will be no necessity to enter into a detailed account of the different systems of pulleys in these lessons. The teacher may show, by means of a black-board sketch, how the advantage gained by using a single movable pulley can be further developed by employing a number.

Show and prove, by following the tension in the cords, that two movable pulleys will enable a **power** *of 1 lb. to support a* **weight** *of 4 lbs.; that with three such pulleys a power of 1 lb. will support 8 lbs.; and with four of them 1 lb. will support 16 lbs., and so on.*

Lesson VI

THE WHEEL AND AXLE

I. Introduction

Commence by showing again the circular wooden disc with which we illustrated the principle of the fixed pulley.

Make the class describe its action. Lead them to explain that it is in reality nothing more than a lever of the first order, having the power at one end, the weight at the other, and the fulcrum between the two.

What can you tell me about the arms of this lever-wheel? They are equal.

What then is the mechanical advantage of such a wheel? There is no advantage in increase of **power**; the arms being equal, the forces at their extremities must also be equal. The only advantage gained by a fixed pulley is in a change of direction. It is easier to pull downwards than upwards.

How would you illustrate this? By the boys on the see-saw. They exert no force; their own weight acting downwards raises the weight at the opposite extremity.

So then in the fixed pulley we have a machine that gives no advantage in force, because the arms of the lever are equal.

Now let us see how this machine suggested another, which should give great mechanical advantage.

II. Principle of the Wheel and Axle

Take another circular disc of wood, exactly like the one already used, but very much larger. Fix it to the pivot on the stand, as we did the one in the former lesson. Place the smaller disc also on the pivot, in front of it, and fix the two discs together

by a screw in such a way that when one revolves the other must revolve with it.

Now to the right of the large wheel and the left of the small one attach separate cords. Pass each cord under its wheel and round the grooved circumference, so that the end hangs from the outer side.

Show that by pulling either cord downwards the other rises upwards. In other words, our machine is, as before, a lever of the first order. Let us see how it differs from the single wheel.

Draw across the smaller front wheel a horizontal diameter. The two radii of this diameter form the two equal arms of a lever, which act on the centre as their fulcrum. At the extremity of the left arm, the cord of the smaller wheel hangs and acts.

Now continue the right arm in a straight line across the larger wheel to its circumference, marking the line plainly so that it may be clearly seen by the whole class.

Remind the class that this larger wheel moves **with the small one.** *The line just drawn across it, from centre to circumference, is a radius of the larger circle. It is the right arm of a long lever, and at its extremity, on the circumference of the wheel, the cord of that wheel hangs and acts.*

Pull the cord hanging from the large wheel. Show how the line representing the horizontal lever is depressed on one side as the cord on that side pulls downwards.

But we notice too that the short left arm of the lever (that radius of the small wheel on the left of the centre) moves upward as the longer arm is pulled downward, because the two wheels move together.

Now who can tell me what we really have in this new machine? We have an application of the levers of the first order, with the arms of unequal length.

Each wheel, as we have already seen, may be regarded as composed of a great number of levers all acting on the centre as their fulcrum, and the combination of the two wheels—a large and a small one—gives the advantage of unequal arms to each lever.

III. How the Machine works

We know from the principle of levers of the first order that a small weight acting at the extremity of the long arm will balance a large weight at the end of the short one, and that the slightest additional weight on either will cause the other to move upwards.

This is the whole secret of the wheel and axle.

Let us suppose the radius of the large wheel to be three times that of the small wheel. Then evidently we have a lever, one arm of which will be represented by three, the other by one.

Draw two circles on the black-board to represent the two discs in position, showing the length of the lever from the circumference of one wheel to that of the other. Make one arm or radius three times the length of the other.

It is clear now that a weight of 1 lb. suspended from the large wheel will balance a weight of 3 lbs. hanging from the small one.

Show with the model that this is really the case.

Now add a small weight, say an ounce, to the 1 lb. on the large wheel. It at once descends, and the 3-lb. weight on the small wheel rises.

Remove the ounce weight, and this time attach it to the 3-lb. weight on the small wheel. This now begins to descend, and as it descends the 1-lb. weight hanging from the large wheel rises.

Who noticed any difference in the rising of the weights on the two arms? The weight on the short arm **moved slowly,** and **through only a small distance.** The weight on the long arm **travelled quickly** upwards, and **moved through a greater space.**

Here we have again the principle that **gain of power means loss of speed; loss of power gain of speed.**

If the radius of one circle had been 4, 5, or 6 times that of the other, the mechanical advantage would have been equally as great. That is, a weight of 1 lb. would have balanced a weight of 4, 5, or 6 lbs. in each case.

Hence the greater the difference between the size of the wheels the greater the mechanical advantage. By making one wheel very small, and the other very large, we get very great advantage of power.

IV. Applications of the Wheel and Axle

1. The windlass for raising the bucket in a well.

Show a picture of this machine, and explain its construction and action. The axle on which the rope attached to the bucket is wound represents the small wheel of our model. The power is applied either to the ends of the spokes of the large wheel or to a long handle attached to the centre of the axle.

Show that when this handle makes a revolution it describes a very large circle. The advantage in gain of power depends upon the size of this circle as compared with the axle.

Thus, suppose the radius of the circle described by the handle to be 2 feet, and that of the axle 3 inches, then a power of 1 lb. applied at the handle would support a weight of 8 lbs. suspended from the axle; and a slight additional power would raise the weight from any depth.

2. The capstan for heaving the anchor on board ship, opening and closing lock gates, etc., is another application of the wheel and axle.

Show a picture of the machine at work, and let the class explain its action.

What is the purpose of the long spokes?

Show that the longer the spokes the more is the power applied at their ends multiplied.

Show too that, as we have already seen, the rope is wound round the axle in a direction contrary to that in which the great circle revolves.

Lesson VII

THE INCLINED PLANE

I. Meaning of the Term

By the term "**plane**" we mean a flat, smooth surface. If that surface is upright like the walls of the room, we call it a **vertical plane.** If horizontal like the floor or the table-top, we call it a **horizontal plane.**

Make the class point out a vertical and a horizontal plane in an open book.

Now raise a leaf into a slanting position, so that it makes an angle with both the vertical and the horizontal planes.

Tell that this also is a plane. We call it an **inclined plane.** *It is neither vertical nor horizontal; it slopes downwards.*

Lead the class to tell that an ordinary **level road** *is a* **horizontal plane**; *the* **road up a hill-side** *an* **inclined plane.**

We usually speak of the slope of the hill. Some hills are steeper than others; we say the **incline** or the **slope** is greater.

It is usual to measure the inclination of an inclined plane by comparing the height with the length of the slope. Thus, if a piece of road 100 yards in length were a yard higher at one end than at the other, we should say that it had an inclination (or a gradient) of 1 in 100.

II. Friction

Provide an inclined plane with a smooth, polished surface for experiment. Place various small objects on it, and show that they all have a tendency to roll down the slope; the smoother they themselves are, the more easily do they move on the smooth surface.

Place the same articles on a rough deal board, inclined at the same angle, and show that they do not move as quickly now. Some of them do not move at all, but remain at rest on the slope.

Call attention to the inequalities and roughness of the board.

Tell that these rough inequalities of the surface cause a rubbing or **friction** *between the body and the board, and that this friction actually causes the moving body to come to a stand-still.*

Compare the huge masses of rock resting on the slope of a hill.

The hill side and the blocks of stone themselves are both rough. It is the roughness of their surfaces that brings the rolling to an end, and causes the stones to remain at rest.

In the inclined plane, that we have now to consider, we must think of the surfaces as being perfectly smooth, **and without friction,** although practically this is never strictly true.

III. The Use of an Inclined Plane

Lead the class to describe how the brewer's draymen move the heavy casks out of their waggons and into the cellars; and out of the cellars into their waggons. They use an **inclined plane.** *Let us see why.*

Suppose I set one of you boys the task of taking to the top of a hill a load too heavy for you to lift, how would you act? If it were a round body that would roll, you would roll it up the hill; if it were something with a flat surface (*e.g.* a box), you would probably attach a rope to it and drag it up.

What kind of hill would present the easier task, one with a steep slope or one with a gentle slope? The boy would find it much easier to roll the load up the gentle slope than up the steep one.

We want now to find out the reason for this; and what mechanical advantage the inclined plane gives. We will return to our smooth, polished plane.

Adjust the plane so as to make its height exactly half the length of the slope. (This will give an incline of 30°.) To the top of the slope fix a small pulley.

To one end of the cord which passes over the pulley attach some smooth, polished object — a ball for example—and let it rest on the polished surface of the inclined plane.

Show the class how to find out by trial what weight hanging from the other extremity of the cord will balance it.

They find that, whatever is the weight of the ball on the plane, it will be balanced by exactly[1] *half the weight at the opposite end of the cord. A slight addition to this will cause the body to move up the incline.*

Alter the inclination of the plane again and again, and test the conditions of equilibrium each time.

Show that the same weight resting on the different slopes will not be supported by the same power at the other end of the cord.

The power varies according to the slope. Thus if the height is one-third the length of the slope, the power necessary to support the body on the inclined plane is only one-third its weight. If the height be one-fourth the length, the proportion will be 1 to 4.

With the height at 1 foot and the slope at 7 feet it would require $\frac{1}{7}$ of a cwt. = 16 lbs. power to support 1 cwt. on the plane.

In other words, the longer we make the slope as compared with the height, the greater is the mechanical advantage.

Tell that, as in former lessons, we have made use of the pulley only for the purpose of measuring the force required.

Whether the body be pushed upwards from behind, or pulled up by means of a cord, the force necessary to accomplish it is the same in each case.

[1] Tell that in theory this is true; but, as we said before, in actual practice there is sure to be more or less friction, even with the smoothest bodies. This friction interferes with the experiment, and the power requires to be slightly greater.

IV. Applications of the Inclined Plane

1. The smooth ladder of the drayman has already been mentioned. This forms an inclined plane.

What kind of a ladder is most advantageous to him—a long or a short one, and why?

2. An inclined plane is often used for transferring a great block of stone into a cart. The rough surface of the stone, in addition to its weight, would prevent it from moving; but in order to overcome some of the friction, three or four rollers are placed under the block, and as these roll forward they carry the block with them, the hindermost one being transferred to the front from time to time as it is disengaged.

3. In the construction of bridges a great deal of care has to be given to the length of the approaches on either side. These slope upwards towards the middle of the bridge; and the slope must be made sufficiently long in comparison with the height, so as not to cause too great a tax on the horses which will have to draw heavy loads over the bridge.

The horse travels with its burden along a level road with comparative ease. The weight rests upon the wheels, and it has only to overcome the friction between the wheels and the rough surface of the road. As soon, however, as it begins to mount a hill it has, in addition to the friction, another force to contend against, the force of gravity, due to the weight of the load; and this increases with the increase of the slope.

4. The road up a steep hill is usually made to wind round and round the hill in order to give a longer slope, and so render the ascent easy.

5. Spiral stair-cases are generally employed for ascending lofty towers, for the same purpose.

Lesson VIII

THE WEDGE

I. Introduction

Show the inclined plane of last lesson. Make the class tell its use as a machine for raising, by means of a slope, bodies too heavy to be lifted.

Why is it so much easier to push or drag the heavy body up the incline than it would be to carry it?

Let them explain too that the mechanical advantage depends upon the length of the slope as compared with the height of the inclined plane.

The one thing we must remember now is that the body to be raised is **actually pushed or dragged up the inclined plane,** while the plane itself remains at rest.

Show now a piece of hard wood cut in the form of an inclined plane.

Insert the thin edge of this plane under some heavy object (e.g. *a large box*) *placed on the table, and push the plane itself forwards.*

What happens? By pushing the plane forwards, we raise the heavy box.

That is, the weight is raised this time, not by pushing it up the inclined plane, but **by forcing the inclined plane under it.**

It is the inclined plane itself that moves, and not the body to be raised.

II. Nature of the Wedge

Now take two such planes, exactly similar in size and shape, and place them together base to base. The two thus joined form a wedge.

Show an actual wedge made of iron or some hard wood. Its two sides are triangular in shape; its faces and top are oblongs; it has a sharp edge.

Divide its triangular side by a line drawn from the apex perpendicular to the base, and show that, if it were cut through along that line, we should get two inclined planes exactly similar.

The wedge, then, is simply a **pair of inclined planes;** or we might better say a **double inclined plane.**

III. Its Uses

Our business now is to learn how to make use of the wedge as a machine for accomplishing certain work.

Call attention to a large cupboard, or some such object in the room too heavy to lift. Suppose I had to raise this heavy body from the floor; how should I do it?

Some will suggest pulleys; some a wheel and axle; some the inclined plane.

Show that these would do very well if we wanted to lift it some distance above the floor.

But it is sometimes necessary to raise a heavy body only one or two inches. No machine will accomplish this so well as the simple little wedge.

Insert the thin edge of the wedge under the cupboard, and call upon one or two of the boys to come and push it, as we did the little inclined plane under the box on the table.

It will not move.

Now take a hammer and strike the wedge a few blows with it. What has happened?

The blows of the hammer have driven the wedge between the bottom of the cupboard and the floor, and as the wedge moved under it lifted the cupboard from the ground.

The heavy body was raised by the moving of the wedge.

Show that the exertion of striking the blow with the hammer was very small compared with the great weight of the body raised.

By employing this little machine, therefore, we have gained a great mechanical advantage.

Tell that, as the power is always supplied to a wedge by a blow with a hammer, and not by pulling or pushing, it is not easy to calculate exactly the mechanical advantage with this machine, as we have done with others.

Notice that the body still remains raised up, just where the wedge carried it. The thin part of the wedge is under it, the thick part outside.

Why does not the weight of the body, pressing downwards, force the wedge out? It would do so if the wedge and the surface of the body itself were perfectly smooth—in other words, if there were no friction.

It is **the friction** between the two **that grips or holds the wedge in its place,** every time the blow of the hammer has sent it a little further in. If it were not for this friction, the wedge would rebound and fly out after the blow had been struck.

This might be well illustrated by employing a wedge for splitting a block of wood. Tell that this is one of the commonest uses of the wedge.

Here the cohesion of the wood is the resistance to be overcome. This resistance is quite powerful enough to force out the wedge, but the friction between it and the wood holds it fast.

This use of the wedge should suggest such applications of it as **axe-heads, knives, chisels, nails, planes,** *etc. It will be easy to show that they are all wedges.*

Lesson IX

THE SCREW

I. Introduction

Refer to the lesson on the inclined plane.

How do we utilise the principle of the inclined plane in making a road over a hill? We lead the road round and round the hill, making it rise gradually.

Tell that such a road is really an **inclined plane,** *and that, as it winds round and round the hill, we may call it a* **spiral inclined plane.**

Show a corkscrew. Point out that this instrument is also made on the principle of a **spiral inclined plane.**

Trace the ascent of this inclined plane from bottom to top It winds round and round a central axis or cylinder.

Illustrate its construction as follows:—Cut a piece of thick white paper into the shape of the section of a long inclined plane, with a slight ascent. Ink the sloping edge, and then wrap it round and round a pencil or a small round ruler. The ink-marked edge of the inclined plane passing round and round the central axis will represent the spiral inclined plane of the corkscrew.

II. Principle of Action

We saw in the inclined plane that the ratio which the **power** bears to the **weight** or **resistance** depends upon the ratio between the height of the plane and its length.

If we want a small **power** to overcome a great **resistance,** we must make the **length** of the slope as great as possible in comparison with the **height.**

Let the boys examine a few screws of different kinds. We usually speak of the central cylindrical part as the **axis**; *the round upper portion as the* **head**; *and the opposite end the* **point.** *The* **spiral inclined plane** *is called the worm or* **thread** *of the screw; the distance between any two of the threads is termed the* **pitch.** *Sometimes the threads are very close together, and we say the screw has a* **fine pitch**; *sometimes they are wide apart, and we then say the screw has a* **coarse pitch.**

Now side by side with the consideration of the thread and the pitch of a screw, we must learn what would be the length of one turn of the screw if it were unrolled—*i.e.* what is the length of the thread once round the screw.

When we know this we can easily calculate the ratio between the power and the resistance.

Suppose, for instance, the **pitch** of a screw to be $\frac{1}{16}$ of an inch, and the length of the thread once round the screw 2 inches. Then as the length of the inclined plane is 32 times greater than the height, any given power applied to the screw will overcome a resistance 32 times as great.

Insert the corkscrew into a cork, or a common screw into a piece of wood.

Show that they penetrate the substance, because thread after thread of their spiral inclined plane moves downwards.

The screw, like the wedge, is a movable machine—a **movable inclined plane.**

The screw is not only used for penetration, but also for pressing substances together.

When used for this purpose it must be provided with a nut. A nut is a hollow cylinder, on the inner surface of which is cut a hollow spiral groove of exactly the size to receive the spiral thread of the screw. The nut itself being fixed, holds the screw fast.

Make the class see that when a screw enters a piece of wood or a corkscrew penetrates a cork, the instrument cuts its own nut or groove in the substance through which it passes.

This is why the threads of these screws are provided with a sharp cutting edge. All other screws have blunt square edges.

We have already spoken of the mechanical advantage of the screw, and you can tell me that it depends upon the ratio that exists between the length of the slope and the height of the inclined plane.

We cannot pretend to learn all about the screw in this lesson; but there is one point which we must consider before we close it.

How do we force the screw into the wood? With the help of a screw-driver.

What enables us to push the cork-screw into the cork? The handle at the top.

Show a picture of a screw-press, and tell how it is worked.

The workman turns the long handle at the top.

Tell that screw-driver, corkscrew handle, and the handle of

the screw-press are all levers. These levers give the power an immense advantage in addition to the advantage provided by the screw alone.

Calculate as follows:—A screw press is provided with a screw of $\frac{1}{4}$ inch pitch, and is worked by a lever which at each revolution sweeps a circle of 15 feet. Now 15 feet = 180 inches = 720 quarter inches. That is to say, the length of the slope of the inclined plane is 720 times as great as its height. Hence the man, by exerting a muscular force of 20 lbs. on the end of the lever, would produce a pressure of $20 \times 720 = 14{,}400$ lbs., or upwards of 6 tons.

Lesson X

WATER AS A MACHINE

I. Introduction

We have lately been discussing certain contrivances which we call **machines.** Each of these machines is employed by man for the purpose of turning to the best account the various **natural forces.**

You remember, of course, that we defined a machine to be "any contrivance for transmitting a force from one point to another, or for altering the direction or intensity of the force."

Make the class give examples from each of the machines of the way these changes are effected.

Now I want to introduce to you another machine, and a very important one—I mean water.

II. Two Important Properties of Water

As we are going to think of water as a machine, it is clear that it must possess certain properties peculiar to itself, which enable it to do the work which other machines do.

To be a machine, as we now understand machines, it should be able **to transmit a force** from one point to another; it should be able **to alter the direction of the force**; it should be able **to increase the intensity or magnitude of the force.**

Water can do these things; and it does them because of two important properties which it—in common with all liquids—possesses.

1. **Water is incompressible.**—This is old familiar ground.

Make the class tell exactly what is meant by it, and how liquids differ from solids in this respect.

Let one of the class prove the incompressibility of water by the help of a boy's pop-gun, as was shown in the earlier lessons.

The first great truth we have to remember now is that **if a vessel of any kind is filled with water, no amount of pressure will force that water into a smaller space.**

2. **Water presses equally in all directions.**

This too is a fact with which the class are quite familiar.

Lead them to think over what was taught in the earlier lessons.

Take the same pop-gun as was used just now, and pierce it on all sides with a number of fine holes. Fill it as before with water, and press the end firmly against the palm of one hand. If now the piston be forced into the other end, a number of tiny jets of water will be seen issuing, **in all directions,** *from the little holes.*

The pressure applied to the piston-rod, in one direction, has been transmitted by the water in every direction.

It is because water is incompressible, and because it transmits pressure equally in all directions, that we are able to employ it as a machine.

The **equal** *pressure should be further explained and illustrated by a sketch on the black-board.*

Draw a section of two tubes, one small, the other very large, with a connecting pipe between them.

If we pour water into one tube, what will happen? It will flow into the other, and the level in both will be the same, because water always finds its own level.

Represent each tube as fitted with a piston, which rests upon the surface of the water.

Suppose the area of the small piston to be one square inch, and that of the large one 100 square inches. Now if liquids transmit pressure equally in every direction, it is clear that **whatever pressure** is applied to the small piston, **will be transmitted, by the water,** to every square inch of the surface of the larger piston.

That is to say, if a pound weight be placed on the small piston, we should expect to find that every square inch of the large piston would be pressed upwards with the force of 1 lb.; the entire upward pressure on the piston being 100 lbs.

Now, as a matter of fact, if we had two such piston-fitted cylinders, a weight of 1 lb. on the small piston could only be balanced by 100 lbs. placed on the large piston. That tells us that the water on the under side of the piston is pressing upwards with a force of 100 lbs., and it derived that pressure from the 1 lb. placed on the small piston.

Hence we see that water is actually a machine :—

It is able to transmit a force from one point to another; it is able to alter the direction of the force; it is able to increase the intensity or magnitude of the force.

III. The Hydrostatic Press

Show a picture of this machine. Tell that it gets its name from two Greek words, **hydor** = *water, and* **stasis** = *standing. It represents the power of standing water.*

It is also known as the hydraulic press. It consists essentially of a small force-pump, connected by means of a pipe with a large and strong cylinder fitted with a piston.

The pump itself, like all other force-pumps, consists of a barrel, fitted with a solid piston, and having, in its floor,

a valve opening upwards. The piston-rod is moved up and down by a lever-handle.

As the piston rises, water rushes up the suction-pipe from the reservoir into the barrel.

Make the class tell why.

At the next descent of the piston, the water is forced downwards, and effectually closes the valve in the floor of the barrel. But water will not be compressed, and hence it finds its way out of the barrel by the only available channel—**through the pipe, and so into the large cylinder.**

The pipe itself, however, is provided with a valve also opening outwards, and this prevents any return of water into the barrel of the pump. The consequence is that each stroke of the pump-handle **forces more water into the large cylinder,** and this water presses upwards upon the great cast-iron piston in it.

This upward pressure of the water causes the **piston,** or **ram** as it is called, to rise vertically.

The larger the surface of this piston, as compared with that of the little piston of the pump, the greater will be the force of the upward pressure.

The top of the ram is broad and flat, and above it is placed a very strong iron plate. The great use of the hydraulic press is to pack wool, cotton, hay, and other light but bulky articles, into a smaller space. If any of these objects be placed on the top of the ram, the pressure of the water will force them upwards against the iron plate, and so compress into a much smaller bulk.

It is also used in raising heavy bodies, such as immense masses of iron plates and other metallic work used in building. Thousands of tons are raised in this way with comparative ease.

Call attention once more to the picture of the press. Note that the ram is an inch or two smaller than the cylinder in which it works. Remind the class that the ram rises only because (1) *the water will not be compressed, and* (2) *it cannot find an outlet.*

Tell that when this press was first invented it was of comparatively little use, because as the force, applied at the pump-handle, sent more water in, it caused a corresponding overflow at the top, between the ram and the sides of the cylinder. The force was lost.

An English engineer, Mr. Bramah, invented a contrivance for overcoming the difficulty.

Show a picture of the Bramah collar.

It is made of leather, and is cut in the form of a hollow ring or circle. This leather ring fits close between the sides of the ram and the cylinder; and the water in the cylinder is able to rise and fill the hollow space formed by the folds of the leather.

Lead the class to think of the boy's leather sucker. The pressure of the air holds it firmly against the stone.

Much the same thing happens to the leather collar.

As more water is forced by the pump into the cylinder, it rises, and presses closer still against the inner side of the leather collar. The pressure holds the leather firmly to the sides of both the cylinder and the piston, and effectually closes the opening, so that there can be no overflow—none of the power is lost.

The press is often known now as the **Bramah press.**

THE DWELLING

(GIRLS ONLY)

Lesson XI

WARMING

I. Introduction

Commence the new subject by leading the girls to talk about the nature of heat, so far as it was dealt with in connection with the lessons on clothing. Make them describe, in particular, the

nature and origin of the internal heat of our own bodies; the ease and rapidity with which that heat leaves the body, unless prevented by some means; why and under what circumstances the heat passes away from the body; how clothing prevents this, and so on.

Why should the heat pass away at all from a hot body? A heated body will part with its heat only when the surrounding air is at a lower temperature than itself.

Our own bodies then part with their heat only because the air all round us is colder than we are. If the temperature of our bodies and the air in the room were the same, there would be no loss of heat.

While we are undergoing any exertion or bodily exercise in the open air, we do not feel cold even when the weather is very severe. The bitter cold air around is robbing us of heat, but the exertion we are undergoing is producing heat within our bodies faster than it can pass away from the surface.

Hence it is that we do not feel cold.

But suppose we sat still for some time on a damp, cold day, what would be the result? We should soon begin to feel cold; we should take a chill, and probably before long suffer for it.

In our quiet, inactive state, the internal heat would not be produced as rapidly as it was being carried away, and there would in consequence be a rapid reduction or lowering of the temperature of the body.

II. Fires for the Purpose of Warming

In our rooms at home we are always, more or less, in a quiet, resting, inactive state. Hence, if the body is to be kept at a healthy temperature, it is necessary that the atmosphere of the rooms should not be allowed to get cold and damp.

We light fires for the purpose of regulating the temperature of the air around us, and thereby maintaining the temperature of the body, and preserving it from chill.

Show that many people, by acting unwisely—thoughtlessly—defeat their ends and court the very evil they wish to avoid.

Lead the class to picture a cold, raw, damp day and some persons seated in a warm, snug room, with the temperature say at 60° or 70°. The fire, of course, warms only the air in that room; outside it is bitterly cold.

What must be the result if a person, after sitting in such a room, goes out into the chilly atmosphere? The sudden change gives her a chill and she takes cold.

Something in the way of an extra garment should always be thrown over the shoulders when passing out from a warmed room into the unwarmed air outside.

Two capital hints will, if followed, prevent much mischief—

1. Spend as much time as possible every day in good bodily exercise in the open air; and in the winter especially learn to move about briskly. This will accustom you to the outer air and prevent sudden chills.

2. Never keep large fires. They make the room too hot for either comfort or health, and the change from such a room to the outer atmosphere is so great, and so sudden, that it is almost impossible to avoid taking cold.

The temperature of the room should never exceed 60° or 65° Fah., and this might easily be regulated with the help of a small thermometer.

III. The Nature of Fuel

Before entering into any discussion upon the nature and properties of fuel itself, it will be well to set the class to describe the mode of making a fire. If it can be done practically, so much the better. Let the class criticise and correct as the work proceeds.

The paper or shavings should be laid loosely at the bottom, care having been first taken to see that the bars are clear and free. The wood is next to be laid lightly and loosely, the sticks crossing each other, and lastly, the pieces of coal (not too large) must be piled up above the wood,

care being taken to avoid close packing, and to leave as many cracks and spaces between them as possible. The match is applied to the paper or shavings, and the flame soon passes from these first to the wood and then to the coal.

Let us see what all this means.

The various substances we use for fuel are wood, coal, coke, peat, and charcoal.

Wood is, as we all know, obtained from the hard solid stems of trees.

What is the chief constituent of all vegetable substance?

Carbon. Quite right; then **the principal part of the substance of the wood is carbon.**

Show the piece of charcoal. Tell that this is pure carbon. Hold it with the small tongs in one gas-flame, while a piece of wood is held in another. Both may be seen to burn; but how do the wood and the charcoal differ in burning? The charcoal (carbon) burns with a dull red glow, but no flame. The wood bursts into flame, and will continue to blaze until it is quite consumed.

Evidently, therefore, the wood contains something in addition to carbon. There must be something to produce the flame. This something is the inflammable gas—**hydrogen.** It is this gas as one of the constituents of wood that makes the flame.

Why should the wooden shavings burst into flame so much more rapidly than the sticks of wood?

Lead the class to tell that, after all, neither of these substances, hydrogen or carbon, would take fire without the presence of a third substance—oxygen. It is this gas which is the real burner, the great consumer.

The reason why the thin shavings blaze up sooner than the thick sticks of wood is that the **oxygen** of the air **can get more readily to the particles in the shavings** than in the solid wood.

Notice also the origin of the material of which paper is made.

This too contains the same constituents, and, as the

paper is thin and porous, the oxygen of the air has easy access to every particle of the substance. The hydrogen takes fire first, and when it has burnt itself out, leaves the carbon in a black charred mass behind. So with the shavings and the wood.

Coal contains exactly the same elements. The greater part of its substance is carbon; but its pleasant blaze is due to the hydrogen which exists in it side by side with the carbon.

Lead the class to talk of the preparation of coal-gas.

The heating of the coal in the closed furnaces carries off all the hydrogen. This forms the chief constituent in the gas which we burn in our streets and houses. That which is left behind is coke.

Does the coke blaze when put into the fire? No. Why not? It has lost all its hydrogen; it consists of carbon, and carbon burns with a dull red glow and no flame.

Remind the class of the dangers of using charcoal as a fuel. It should never be used unless there is a constant and free draught for carrying off the carbonic acid which is the product of the burning.

Many persons have lost their lives from sleeping in a closed room in which a charcoal fire has been burning.

Lesson XII

CLEANING

I. Importance of Cleanliness in the Dwelling

Our earlier lessons have shown us the importance of personal cleanliness if we wish to be healthy and happy. It is equally important to keep our homes clean. In fact, the two must go together.

We cannot prevent dirt and mud and dust finding their way into our houses; but we can prevent them from accumulating. It is the business of house-cleaning to

remove every particle of dirt before it has time to work mischief.

Impress upon the girls the fact that dirt not only spoils the appearance of the room and injures the furniture in it, but is a positive mischief to health.

Dirt harbours disease. There is no greater enemy to disease than cleanliness.

Tell that the dust and mud carried into our houses from the roads contain finely divided particles of decaying animal and vegetable matter. These if allowed to accumulate on floor, carpets, and mats, will give off poison-vapours as they decay, and poison the air of our rooms.

Show from this, moreover, the uselessness of keeping the inside of the house clean if we allow an over-charged dust-bin or a rubbish-heap to stand and give off its poison-vapours just outside.

Point out that besides being essential to health, cleanliness in our homes has an important bearing on our daily comfort and our self-respect.

II. System in Cleaning

The great secret in keeping the house thoroughly clean is to set about the work systematically.

The good housewife cares little about having what some people call a "regular turn out" now and again. Her habit is to constantly keep things clean when they are clean, and not to give dirt time to accumulate.

To do this, she so arranges her work that each day has its own regular round of duties; and every part of the dwelling passes regularly through her hands.

She is never in a muddle from top to bottom, for whatever part of the house is being cleaned, the rest is always left neat and tidy.

Show the other picture—that of the house which has its "regular turn out" every Saturday, but is, to a large extent, left to take care of itself all through the week.

The people of such a house begin by trying to be a little

clean. They give the dirt time to accumulate, and it becomes their master. When they do commence cleaning, they generally find there is too much to do in the time, and the natural result is that something gets left after all.

Their trying to be only a little clean is more trouble to them than if they went systematically to work to be thoroughly clean.

The various operations in house-cleaning come under the head of sweeping, dusting, and scouring.

III. How to clean a Room

1. **Sweeping.**—The dirt which finds its way into our houses is either **dry** dirt or **wet** dirt.

Dry dirt settles in the form of dust upon the floors, mats, carpets, and furniture, and can be readily removed by sweeping and dusting.

Before the sweeping begins, mats, rugs, and all carpet which is movable should be taken to the open air to be shaken; the windows should be opened top and bottom; the heavy articles of furniture, such as the couch, sideboard, book-case, piano, or (if it be a bed-room) the bedstead, wash-stand, and dressing-table, should be covered up with an old sheet; the smaller pieces of furniture, such as chairs, etc., may be either stood in the middle of the room or turned out altogether.

The first step in the cleaning operations should be to polish the stove and fire-irons. Why?

Considerable care is required in sweeping a room, or the dust and dirt will be simply transferred from one spot to another, and will not be effectually removed from the room.

A soft hair-broom should be used for the bare boards, but a stiff broom is better for a carpeted floor. A carpet should always have a daily sweep, because the dust and dirt, if left, will grind into it, and will remain there, not only to become injurious to our health, but also to rapidly wear out the carpet.

Two hints are very necessary to young people with regard to sweeping a room.

The first is "Don't forget the corners." The middle of the room will be sure to take care of itself.

The second is, "Don't jerk and bustle and flack the broom about here and there, but pass it lightly over the floors, or you will send the dust flying upwards in dense clouds, to settle, by and by, on the walls, furniture, and pictures."

People who do this merely remove the dirt from the floor, where it is removable, and transfer it to places where it settles and accumulates, and becomes forgotten.

The careful housewife strews the floor and carpets, before sweeping, with damp tea-leaves; the dust, instead of flying about, adheres to the tea-leaves.

All the dust should be swept into one place, either towards the door or the fire-place—not a corner—gathered up with a soft hand-brush into a dust-pan and carried away.

The dust will now require some time to settle, during which the carpet, rugs or mats, may be shaken and laid down again, and the various articles of furniture replaced.

2. **Dusting.**—Each article of furniture, as well as all corners, ledges, pictures, and ornaments, should be carefully dusted with a dry duster. Don't use a damp duster, for the dust will stick to it, and will merely be carried from one article to another, and scratch the furniture each time.

Never shake the duster in the room, or all the work will be undone. It is useless, too, to simply try and flack the dust away, it must be wiped off carefully.

Shake the duster frequently in the open air, or the dust on it will scratch the furniture.

3. **Scouring.**—Under the head of scouring will come the scrubbing of floors, the cleaning of paint-work, the cleaning and polishing of furniture, and the scouring of all tin, copper, brass, steel, and iron utensils.

A few simple hints are all our space will allow us to give here.

(*a*) **Scrubbing a floor.**—Never wet the boards till all dust and dirt have been swept away. A little clean sand is better for scouring than either soap or soda; soap makes the boards black, and soda turns them yellow.

They are useful for removing grease stains, but when floors are scrubbed regularly, "elbow grease" is a better scourer than soap or soda.

Commence at one end of the room, taking a piece which you can easily reach. Take care of the corners; and, when you pass to the next piece, be sure and cover well the edges of the piece already done, or it will leave a black water-mark.

In the scrubbing itself, just swill the boards with the flannel, and then scour them briskly the way of the grain. After the scrubbing, wash them well with the flannel; and if they are not quite satisfactory, scrub them and wash them again.

Take care not to leave the floor wet. The house-flannel should be thoroughly wrung out, and a drying cloth used the last time. Change the water frequently. It is impossible to get clean, white boards with dirty, muddy water.

If scrubbing has to be done in damp, cold, foggy weather, a fire should be lighted in the room to dry it quickly.

(*b*) **Cleaning furniture.**—Before commencing to polish furniture, be sure to see that the dirt is all removed, or your "elbow grease" and furniture-polish will end in scratching its smooth surface.

The best and simplest furniture-polish is made of linseed-oil, turpentine, and bees'-wax. A piece of flannel should be used for laying on the liquid, and a soft dry cloth for the actual work of polishing.

(*c*) **Scouring metallic articles.**—The various metallic articles and utensils about the house are cleaned and polished in various ways.

Tins (*i.e.* all kind of "tinned" utensils) are best cleaned with whiting. The wet whiting paste is first rubbed on

the surface with a piece of coarse flannel; and then a soft rag and wash-leather are used with dry powdered whiting for the actual polishing. **Copper and brass articles** are best cleaned and polished with rottenstone and oil.

Iron articles (*e.g.* the stoves) are kept polished with black-lead. The actual polishing is done with a brush, and not with cloths. Be careful not to lay on too much black-lead.

Steel articles are polished best with emery cloth.

Lesson XIII

VENTILATION

There have been in the previous courses several lessons dealing with the subject of ventilation. The purpose of the present lesson should be to gather up the threads of what has already been taught, and make the teaching as practical as possible.

I. How Good Air is spoiled

If I were to ask you to tell me how it is that the good air which Nature supplies becomes polluted and loaded with poison, you would at once begin to tell me of the carbonic acid which finds its way into the air. You would tell me readily enough that this carbonic acid is poured out into the air as one of the products of all burning; and that animals of all kinds load the air with this gas every time they breathe.

All this is quite true; but unfortunately carbonic acid is not the only poison that lurks in the air, and renders it bad and unwholesome.

Lead the class to think of the pure fresh air as Nature supplies it in the open country, and contrast it with the close, stuffy, and often badly-smelling air of towns.

This great difference is not due entirely to the presence

of carbonic acid sent out by the inhabitants of the town and their fires.

The carbonic acid, poison though it is, is almost inodorous; it cannot be that, then, which produces these bad smells.

Tell that, in a walk through the town, we should probably find dirty streets, lanes, and roads. Our last lesson has shown us that what we call dirt and dust are really finely divided atoms of decaying matter. These particles float about in the air, and settle upon everything; and as they decay they pour out their poison-vapours into the air. The decomposition of animal and vegetable matter always gives rise to bad-smelling, poisonous gases.

Think of the thousands of dust-bins and rubbish-heaps, many of them ill-kept and overloaded; to say nothing of stables, pig-sties, slaughter-houses, gas-works, and factories of various kinds. The bad odours from all these pollute and poison the air.

But with all these bad influences at work, how is it that the air of our towns does not become totally unfit to breathe?

The wind is the great cleanser of the air. If the air of our streets, lanes, and roads were stagnant, these bad gases and vapours would accumulate, and in a short time no living thing would be able to exist in it.

The wind, however, blows away and disperses all the poisoned air, and supplies its place with purer and better air from outside.

Tell of the evil effects of bad drainage. The stream of refuse matter which is being carried away along our drain-pipes and sewers is constantly giving off poisonous gases as it flows. If, through any defect in the construction of the drains, the slightest crack is left open, these poison-vapours escape from the pipes, and pass upwards again into the house.

It frequently happens that, during the day-time, when probably the doors and windows are open, these bad gases may pass unnoticed—the wind disperses them as quickly as they rise. But at night with the house closed up they

have no way of escape, and it is then that they work their mischief.

Remember that these deadly vapours always announce their presence with their offensive odours. This is Nature's warning. Never neglect it. Never rest contented with a bad-smelling drain in your homes.

Remember too that just as the outside air is contaminated by that with which it comes into contact, so the air in our dwellings must become contaminated if it flows past dirty curtains, dirty walls, dirty floors, dirty corners.

II. How Poisoned Air is removed

We must purify the air in our dwellings, schools, workshops, churches, and other buildings where people meet, as Nature purifies the air of the roads and streets. We must make a wind to drive away the foul, poisonous gases.

The great difficulty in the way of doing this is to change the air of the room without causing a **draught.**

We all know what is meant by a **draught.** It is a current of air, colder than the air of the room; and it enters the room at one point, flows through it, and passes out at another.

The danger of such a current is that, as it is so much colder than the air of the room, to which the inmates have become accustomed, it strikes every one with a chill as it passes, and so gives rise to colds and a multitude of evils. The work of purifying the atmosphere of the room, without causing a draught, is the difficult art which we call **ventilation.**

Lead the class, by means of a few simple questions, to mention the hints on this subject given in the earlier lessons, in some such way as this:—

What is the simplest and quickest way of ventilating a room?

How would you let out the foul air?

Why is it not necessary to take much trouble about the means of letting in the fresh air?

Why is there no fear of draught with only the upper sash of the window open?

Why is a fire a good ventilator for a room?

Why should dust-bins and rubbish-heaps not be allowed near the house?

How would you provide for a good supply of fresh air in a bedroom all night?

How would you ventilate the bedroom in the day?

After dealing with these simple methods of keeping the air of the dwelling pure, pass on to consider a few of the commonest mechanical contrivances for ventilation, such as—

1. Perforated zinc panes in the upper part of the window-sash.
2. Gratings in the upper part of the wall just below the cornice of the ceiling.
3. The chimney-valve fitted into the front of the chimney just below the ceiling. It opens to let foul air pass out of the room and up the chimney, but will not allow any return draught from the chimney into the room.

LESSONS FROM CHEMISTRY

(BOYS AND GIRLS)

Lesson XIV

ELEMENTS AND COMPOUNDS

I. Meaning of the Term Compound

Put a little red oxide of mercury into a test-tube of hard glass, and heat it carefully over the spirit-lamp.

The children have seen this red powder before, and know that

it was used in one of the earlier lessons in the preparation of oxygen. Make them tell all about it now.

By simply heating the **solid powder** *over the flame we make it give off* **an entirely different substance—a gas —oxygen.**

Our business now is not to collect the gas for further experiment, but merely to show that it is coming off.

How can I do this? By holding a red-hot splinter of wood over the mouth of the tube.

Do this; and show that the red-hot splinter bursts at once into a brilliant glow. Make the class tell the reason why.

We know, then, that this red powder contains the gas oxygen.

Call attention next to the inside of the tube.

What are these little silvery-white, shining globules all round the sides of the tube? They look like little balls of silver. They are not at all like the red powder we put into the tube.

Tell that these little balls are tiny particles of the metal **mercury.**

If we continued to heat the powder till we could get no more oxygen from it, and then stood the tube aside for a while to cool, we should be able to scrape off, and pour out, the shining drops of liquid mercury, and leave the vessel empty.

The red powder, therefore, which is a mass of minute **solid** particles, contains a **liquid** metal—**mercury,** and a **gas—oxygen.** We call it **oxide of mercury.**

And not only so, no amount of heating or testing the powder could make it yield anything but these two substances—mercury and oxygen.

We say, therefore, that oxide of mercury is a **compound substance**; it is made up of two other substances —mercury and oxygen.

Let us take another experiment.

Show two pieces of chalk or limestone. Place one piece in the middle of a bright red fire, and, while it is heating, proceed to deal with the other piece, in some such way as this:—

What would happen to the chalk if I were to pour some dilute hydrochloric acid over it? It would give off carbonic acid gas.

As our present business is not to prepare and collect carbonic acid gas, but merely to show that it passes off from the chalk, it will be sufficient now to put a piece of the chalk into a basin, and pour some of the dilute acid over it.

Call attention to the bubbles rising up through the liquid.

Those bubbles are bubbles of carbonic acid gas, and the **gas** came from the **solid** chalk.

Remove the other piece from the fire, and, while it is cooling, lead the class to tell all they can of the gas—**carbonic acid.**

It is composed of two substances, the **solid** substance **carbon,** and the **gas oxygen.** Therefore carbonic acid itself is a **compound substance.** We can make it for ourselves by burning **carbon in oxygen.**

Now let us look at the piece of chalk that has been in the fire.

Place it on an earthenware tray, and pour hydrochloric acid on it as before.

It does not now give off bubbles of gas, as the other did. Why not? The heat of the fire has driven off all the carbonic acid it contained, and the substance we have here now is not chalk. It is lime. **In its present state we call it quicklime.**

So then the piece of chalk is a **compound substance** which is made of **lime, carbon, and oxygen.**

Now notice what takes place when I pour **water** *on this hard, solid* **quicklime.** *The water disappears—it seems to be sucked up by the solid substance; tremendous heat is generated; and the solid substance falls away in powder.*

We call this powder **slaked lime.**

Let us see what has happened. The solid substance, **quicklime,** has become united with the water. We say that the two have combined to form a new **compound substance, slaked lime.**

Refer to other experiments which have been shown, and lead the class to tell that whenever heat is produced (whether it be

from the burning of a taper, the action of sulphuric acid on zinc, or water on quicklime), chemical combination is taking place.

II. ELEMENTS

In our first experiment we made one compound body, **red oxide of mercury,** resolve itself into two distinct substances—the liquid metal **mercury,** and a gas **oxygen.**

No one has ever been able to split up either of these substances into simpler kinds of matter. It is impossible to get anything from oxygen but oxygen ; and it is equally impossible to get anything from mercury but mercury.

Hence we say that **oxygen and mercury are elements.**

In our second experiment we separated chalk into two distinct substances—**lime** and **carbonic acid gas.** The lime can be further split up into **oxygen** and a **metal** called **calcium,** which bears some resemblance to the metal **sodium.** Lime is therefore an **oxide of calcium. Calcium itself is an element.**

The other constituent of the chalk—**carbonic acid**—is, as we already know, a compound in itself. It is composed of the solid substance **carbon,** and the element **oxygen. Carbon** is a simple body, and will yield nothing but carbon. It cannot be split up or separated into anything else. **Thus we know that carbon is an element.**

The children should now be made to tell, from what they have already been taught, that **water,** *simple substance as it looks, is in reality a* **compound.** *It is composed of the two gases* **hydrogen** *and* **oxygen.**

Hydrogen gas is a body in its simplest form. We can get nothing but hydrogen from it. **Hydrogen, then, is an element.**

III. SOME OF THE COMMONEST ELEMENTS

The chemist has been able by experimenting on the various substances—solid, liquid, and gaseous—which exist

in, on, and around the earth, to find sixty-four distinct simple bodies or elements.

That is to say, the earth and all it contains are built up of one or more of these sixty-four elements.

Some of these elements, *e.g.* **oxygen, hydrogen, nitrogen, and chlorine,** are gases; **mercury** is a liquid; but the greater number of them are solids.

Among the solid elements, iron, silver, gold, copper, tin, lead, zinc are **metals**; carbon, sulphur, and phosphorus are known as **non-metals.**

In all there are forty-nine metallic elements and fifteen non-metallic elements.

Show that these sixty-four elements combine to form compounds much in the same way as the twenty-six letters of our alphabet combine to form words.

Nearly every word we use is a compound of two or more letters, and the letters make totally different words according to the manner in which they are combined.

Just in a similar way the chemical elements may be called the alphabet of chemistry, and they form various compounds as they vary in their mode of combining.

Thus we might say that **red oxide of mercury** is like a word of two letters—**mercury** and **oxygen.**

Water, a compound of **hydrogen** and **oxygen**; and **carbonic acid,** a compound of **carbon** and **oxygen,** are two similar words.

Chalk would then represent a word of three letters—**lime, carbon,** and **oxygen**; and slaked lime—**lime, hydrogen,** and **oxygen**—would be another similar word of three letters.

As we learn to read and understand these words better we shall find that some of them are very long, and, like the hard words in our books and newspapers, contain a great many letters.

Lesson XV

CHEMICAL COMBINATION

I. Chemical Affinity

Show the bottle containing the metal **potassium.** *Tell the class that this is one of the metallic elements, but it is a very different metal from iron, lead, tin, or any they are familiar with. It has to be kept in this bottle, in paraffin, or rock-oil. Presently we shall see why.*

Remind them that we have already met with an element, **phosphorus,** *that must be kept in water; but water is not able to keep this element*—**potassium**—*out of mischief; we have to employ paraffin.*

Take it out of the bottle, cut off a small piece about the size of a pea, and throw it into a large basin of water.

It is so light that it floats on the surface, but the most wonderful thing of all is that the moment it touches the water, **it seems to burst into flame.** We see the beautiful purple flame playing all round it as it floats about on the surface.

The piece of metal gradually becomes smaller and smaller, and at last disappears entirely.

Now let us see what all this means.

You saw that we had to keep the potassium in paraffin. The fact is, **this metal has such a great liking for oxygen,** that if it were left exposed to the air it would go on abstracting oxygen from it.

The two elements could not keep apart; they would rush together to form a new compound substance.

We cannot keep it in water even, for **it would rob the water of its oxygen** for the same purpose. Hence we bottle it up in paraffin.

Cut another small pellet, and call attention to the bright, bluish, metallic lustre of the newly-cut surface.

Let the class notice that even while they are looking at it the lustre disappears.

Tell that the metal, immediately it was exposed to the air, began to rob the air of oxygen, and to combine with that oxygen to form a new substance all over its surface. It is this new substance which dulls the lustre of the newly-cut surface.

I wonder whether you can tell me now the meaning of the flame on the water.

The moment the potassium touches the water, **it begins to rob it of some of its oxygen.**

Now as water is composed of only the two gases oxygen and hydrogen, what must happen when the metal takes away some of the oxygen?

A certain amount of hydrogen must be set free.

The potassium and oxygen and some of the hydrogen combine and form a new compound substance—**caustic** potash, which dissolves and might be discerned in the water.

In other words, **the oxygen,** set free from the water, **burns up or oxidises the potassium,** the result of the oxidation being the new substance—caustic potash.

We have already seen, however, that wherever chemical combination takes place heat is given out.

Now then let us see. Hydrogen, a very inflammable gas, is set free all round the floating piece of metal. This metal combining with oxygen gives off heat.

Then the burning flame is really the hydrogen set free from the water and blazing round the floating pellet of potassium.

All this takes place because of the great **attraction** that potassium and oxygen have for each other. We call this attraction **chemical affinity or chemical attraction.** It is another very important "force" in nature.

It was this chemical attraction, or chemical affinity, that enabled us in the last lesson **to obtain carbonic acid from chalk,** by means of hydrochloric acid. The lime of the chalk has a stronger affinity for the chlorine of the hydrochloric acid than for the carbonic acid. It con-

sequently breaks its connection with the carbonic acid and enters into new relations with the chlorine, forming a new substance, chloride of lime, and setting free the carbonic acid.

It is the strong affinity of phosphorus, sulphur, carbon, and hydrogen for oxygen that causes them to burn so fiercely in that gas.

Let us see what we have learned from this—

1. Certain elements have an attraction or affinity for others.

2. This attraction does not exist between all bodies, and it differs in degree. It is stronger between some than others.

3. It is so strong in some that they at once unite if they are brought into contact.

4. In others, heat must be applied to start the chemical action.

II. Chemical Combination

Refer to the experiment of pouring water on quicklime; or better still, repeat it now.

Point out the strong affinity between the quicklime and the water, as shown by the greedy avidity with which the lime drinks in the water.

The two actually combine to form a new substance—slaked lime; and while they are combining they evolve great heat.

Take a small glass flask; put some flowers of sulphur in the bottom, and in the sulphur a small coil of fine copper wire. Place the flask on the iron stand, and heat it gradually and gently over the Bunsen burner or the spirit-lamp.

N.B.—*The lamp and the iron stand should both be placed on a tray to catch the sulphur in case of the flask bursting with the heat.*

Let the class note what happens. First the yellow powder melts, and becomes liquid sulphur; then it begins to change

colour, till it is at last quite black. By this time the liquid boils.

The copper wire, however, has by this time also become very hot, and now in contact with the boiling sulphur begins to glow with an intensely bright light and great heat. The solid metallic copper melts and seems to disappear.

Let the flask be removed now and set aside to cool. When it is cool, break it open, and show that it now contains neither sulphur nor copper, but a black, solid substance, quite unlike either.

The **copper and the sulphur have combined to form this new substance,** which contains in itself every particle of the two original elements.

While they were uniting in this way they gave out intense heat; it was this heat that melted and burned the metallic copper.

The great thing to remember in this chemical combination of two or more elements is that, though each element is present in the compound, and can be recovered from it, it loses entirely its distinctive properties while it is in combination.

Show once more some of the **red oxide of mercury,** *and make the class tell its constituent elements.*

Here is a red powdery substance. Who would expect to find in it the bright, shining liquid metal mercury, and the gas oxygen?

Yet we know that, although the powder itself possesses none of the properties of either mercury or oxygen, both these elements are present in it, and can be obtained from it. When so obtained, moreover, both the oxygen and the mercury are found to possess all their usual properties once more.

Lesson XVI

COMBUSTION

I. Meaning of the Term

Have two or three jars of oxygen prepared beforehand in readiness for the lesson. Repeat the experiments with the red-hot splinter of wood and the pieces of carbon, sulphur, and phosphorus. With all these the class ought to be familiar.

Let them burn first in the air of the room, and afterwards in the oxygen. Call attention each time to the striking difference in effect.

Why do these things burn at all in the air? Because the air contains oxygen.

What does the burning mean in each case? It means that each of these substances has an affinity or attraction for oxygen; and, because of that affinity, it abstracts oxygen from the air, and enters into chemical combination with it to form a new compound substance.

The wood and the charcoal did not burn as briskly as the sulphur, nor the sulphur as briskly as the phosphorus. Why? The chemical attraction of all these substances for oxygen is not equally strong. That of phosphorus, as we have seen, is so strong that unless the element is kept in water it takes fire and burns away.

Call attention now to the powerful burning and the brilliant dazzling glow that takes place when these substances are allowed to burn in the jar of undiluted oxygen.

The action which has taken place in the air and in the jar of oxygen is precisely the same in kind; it differs only in degree. In either case it was entirely due to the presence of oxygen.

Each of these substances combined with oxygen to form a compound, and while combining gave off more or less heat and light. This is just what we mean by the term **combustion.**

If the large, bottomless, stoppered jar that was used for the separation of nitrogen from air can be filled with oxygen, a simple and very brilliant experiment may be shown with some of the thinnest of iron wire.

Form the wire into a spiral by coiling it round a cylinder of some sort. A small round ruler will do. Fix one end of the spiral into a cork, which exactly fits the neck of the jar; and tip the lower end with brimstone by first heating it and then dipping it into flowers of sulphur.

The jar, well stoppered, should be filled with oxygen at the pneumatic trough, and then stood on a slab or an iron tray.

The sulphur-tipped end of the iron wire must be then heated, the stopper rapidly removed from the jar, the wire inserted, and the cork to which it is fixed pressed well down.

Now we see the same thing taking place with the metal, iron. Chemical action is going on fiercely. The iron and the oxygen are entering into chemical combination, giving out meanwhile intense heat and a most dazzlingly brilliant light.

White-hot, fused drops of the newly-formed compound are seen to fall continually as the burning proceeds.

Combustion is going on, in other words, **between the iron and the oxygen.**

As this kind of chemical action cannot take place without the presence of oxygen, **we always speak of oxygen as the great agent of combustion.**

II. Products of Combustion

Let us commence with the combustion of the piece of carbon or charcoal, either in the air or in the pure oxygen.

Why does the carbon burn? Carbon, when once it is heated, has a strong affinity for oxygen. It combines with the oxygen to form a new substance, carbonic acid gas; and while the combination is going forward, heat and light are produced.

We have already learned that coal, wood, coke, peat—

everything we use as fuel—as well as the coal-gas, paraffin and other oils, and candles, which we use for lighting purposes, consist largely of the element carbon. None of them would burn in an atmosphere deprived of its oxygen.

The burning of any one of these will illustrate clearly what is meant by the term **combustion.** It is simply the chemical combination of the substance which is being burned with the oxygen in the air all round it.

The carbon so burned is not destroyed. It is merely changed into a new form in combination with oxygen as carbonic acid gas.

We utilise for our own purposes the heat and light given out by these substances during combustion. The poisonous product carbonic acid is made to disperse as rapidly as possible.

Tell that whenever combustion takes place—that is, when any substance unites chemically with oxygen—we use one word to describe the new compound formed. We call it an **oxide.**

For example, the piece of sulphur burned with a pale blue flame, and gave off the well-known powerful smell which we are familiar with when we strike a lucifer match. This smell came from **the newly-formed compound of the sulphur and the oxygen,** which we may call an **oxide of sulphur.**

So with the burning phosphorus and the iron wire. In each of these cases the product of the combustion was **an oxide of phosphorus** and **an oxide of iron** respectively.

In like manner we may have oxides of lead, zinc, copper, tin, mercury, lime, etc.

Show some iron rust. Tell that this is **oxide of iron.** *This reddish powder is a compound of iron and oxygen. The combustion which formed it was so slow that the usual heat and light were not evolved.*

III. WATER

Just one more thought about **combustion** before we leave the subject.

What is the name of that very inflammable gas which takes fire immediately a flame is brought near it? Hydrogen.

I want some hydrogen now; you shall tell me how to prepare it.

Lead the class to tell the different steps in the preparation of hydrogen, and why it is necessary to expel all the air in the bottle before we experiment with the gas. The bottle at first contained a certain amount of air, and if any of that air were allowed to mingle with the hydrogen, there would be an explosion, as soon as a light was brought near it.

Why should there be an explosion? Let us see.

Fill an ordinary soda-water bottle with water, and invert it over the pneumatic trough. Let the hydrogen from the delivery-tube displace about two-thirds of the water; then remove the tube, and fill the remainder of the bottle, in like manner, with oxygen.

What have we now in the bottle? We have a mixture of the two gases hydrogen and oxygen; and there is twice as much hydrogen as oxygen.

Bind a thick towel well round the bottle, hold it firmly in one hand, with the mouth turned away from the class, and bring a long, lighted taper near.

Explain that the sudden, violent explosion that follows is due to the strong **affinity** *that hydrogen has for oxygen. While the two gases were merely mixed together in the bottle, no explosion took place, but the only thing wanted was a flame.*

But what has become of the two gases now? The next experiment will tell us.

Fit the small glass jet-tube to the cork in the hydrogen bottle, in place of the long delivery-tube, and pour a few more drops of sulphuric acid down the funnel-tube.

Hydrogen will be again given off, and may be lighted as it escapes at the jet.

Hold a tumbler or a large test-tube over the flame, and show that in a short time it becomes covered inside with a dew-like deposit. **The hydrogen has burned and formed water.**

We have another instance of **combustion.** Hydrogen and oxygen have united chemically to form a new substance, water; and while uniting have evolved light and heat.

The combustion goes on quietly here because only a very small quantity of hydrogen can escape from the jet at one time.

When the gases were mixed in larger quantities in the soda-water bottle, the combustion was very sudden and very violent, and we had a loud explosion.

Then, as now, the two gases combined to form water. **Water always consists of these two gases hydrogen and oxygen chemically united in the proportion of two to one.**

Lesson XVII

THE AIR A MIXTURE OF GASES

I. Introduction

Refer to the last lesson, and lead the children to think about the experiment with the soda-water bottle.

They saw the bottle filled with the two gases hydrogen and oxygen, in exactly the proportion in which they exist in water, viz. twice as much hydrogen as oxygen.

The bottle might have been corked securely in that state, and left for any length of time, and in the end it would contain, not water, but merely a mixture of the two gases. Each gas too would still possess its individual and distinctive properties.

This would be seen immediately a flame was brought near. The inflammable **hydrogen** *would take fire in presence of* **oxygen,** *the agent of combustion; there would be a bright flash, and a loud report; and the two gases would then lose their individuality, and become chemically united to form a totally new substance—water—possessing the characteristics of neither.*

II. Composition of the Air

Lead the class next to tell that atmospheric air consists of two gases, nitrogen and oxygen; and then proceed, under their direction, to repeat the experiment (which has been already shown) of separating the nitrogen from the air in the bell-jar, or the bottomless jar used in the last lesson.

Explain that it is not absolutely necessary to burn **phosphorus** *in the jar. A piece of candle would accomplish the same thing; for it would, by its combustion, use up all the oxygen, and leave the nitrogen behind in the jar. Its own flame too would die out when all the oxygen was exhausted.*

One reason why we use phosphorus in preference to a taper or a piece of candle is that **it burns so much more rapidly.** It would be a very slow process with the candle.

When the white fumes of the burning phosphorus have disappeared, make the class explain why the water has risen in the jar, and to what extent it has risen. The water has simply taken the place of the oxygen, which has been removed.

That which is above the water, in the upper part of the jar now, is the gas **nitrogen.**

The jar of air originally contained four times as much nitrogen as oxygen. **Four-fifths of the jar is now filled with nitrogen.**

Show again the peculiar and distinctive properties of nitrogen by plunging a burning taper into it.

Nitrogen is characterised by negative properties. **It is uninflammable itself; and it does not support combustion in other substances.**

But we actually saw the phosphorus burning in the jar of air. Why did it burn?

Because, although four-fifths of the air in the jar consisted of nitrogen, a non-supporter of combustion, the remaining one-fifth was oxygen, and it was the oxygen that supported the combustion.

But water contains more oxygen in proportion than air, for one-third of its bulk is oxygen; **and yet we know**

that the oxygen in the water cannot support combustion. Water effectually extinguishes all flame.

Why should the oxygen in the air be able to do what the oxygen in the water cannot do?

III. THE GASES ARE MIXED, NOT CHEMICALLY COMBINED

Explain—1. *That, although water contains a large amount of oxygen, the oxygen is in chemical union with the other element, hydrogen. It is not free; it forms, for the time, an inseparable constituent of a new substance—water; it has lost all its own distinctive properties. The properties of water are totally different from those of either of its constituent gases.*

2. *That the oxygen and nitrogen, as constituents of air, have entered into no chemical union. Each is free; each retains its own individual properties.*

The oxygen of the air is still the agent and promoter of burning or combustion, although it has lost much of its power. It acts less violently in air because it is diluted with four times its bulk of nitrogen, a gas that, of itself, extinguishes all burning.

Compare a wine-glass full of brandy diluted with four such glasses of water.

It would be very interesting now to prepare some oxygen in the usual way, and pass the end of the delivery-tube under the jar, filled as it is with one-fifth water and four-fifths nitrogen. As the oxygen comes off, it will pass upwards through the water into the jar, the water itself being displaced to make room for it.

When all the water has left the jar, lead the class to tell that we have in it now a mixture of the two gases, oxygen and nitrogen, the quantity of nitrogen being four times that of the oxygen.

Call attention to the fact that there was no flash, no heat, no explosion when these gases mingled. They are not chemically united—they are merely mixed as we might mix salt or sugar with sand; water with vinegar or wine.

Now take the lighted taper and plunge it into the mouth of the jar. The taper burns inside as well as it does outside the bottle, but no brighter. It went out at once in the pure nitrogen;

but now we have a mixture of nitrogen and oxygen. It is the diluted oxygen which maintains the flame of the taper.

We have made a jar full of ordinary atmospheric air.

Lesson XVIII

CHLORINE

I. How to make the Gas

Mix in a mortar equal quantities of common salt and black oxide of manganese, and put the mixture into a glass flask, fitted with a long bent delivery-tube. The end of the bent tube dips down into a dry bottle.

Next dilute a little sulphuric acid with an equal quantity of water, and when cool pour it down the funnel on to the mixture in the flask, till it assumes the appearance of a thin paste.

If now a gentle heat be applied to the flask, a dense, yellowish-green gas will be seen to rise rapidly, and pass along the delivery-tube into the dry bottle.

This is the gas **chlorine.** It is a heavy gas—2½ times heavier than air. Hence as it collects in the bottom of the bottle it forces the air out at the top. It is collected, as we sometimes say, by displacement.

When a sufficient number of bottles have been filled, they should be covered, and all the rest of the apparatus removed from the room.

Care must be taken to avoid breathing any of the gas while experimenting with it, for it is a violent irritant, and will cause coughing and throat inflammation.

II. Its Properties

Put into the deflagrating spoon a piece of phosphorus about the size of a pea, previously dried in blotting-paper. Lower it into one of the jars of chlorine, but do not light it.

The phosphorus immediately takes fire, and burns in the chlorine with a pale green flame, till it is all consumed.

Keep the bottle covered and set it aside.

Introduce into another bottle a leaf of Dutch metal. Show it beforehand, and tell that it consists chiefly of copper. We may call it copper-leaf.

In the chlorine gas this copper-leaf at once ignites, and burns with a smoky flame.

Now, before going further, let us think over what has taken place.

In each case we have seen a spontaneous chemical action going on. Both the phosphorus and the Dutch metal ignited of their own accord in the jars of chlorine gas.

In the first bottle the **phosphorus** united with the **chlorine gas** to form a **new compound**, giving off light and heat during the combination.

In the second bottle the **copper** also united with **chlorine** to form a **new compound**, and in this case too heat and light were evolved during the combination.

Now we have already given a name to this kind of chemical action. What is it? We call it **combustion.**

Lead the class to remember that we have hitherto always associated oxygen with the act of combustion.

Here, however, we find a new gas—**chlorine**—as a supporter of combustion, and we see that the usual heat and light are evolved during the chemical combination.

We have spoken of new compounds formed by these acts of combustion.

Tell that chlorine combines with other elements and forms **chlorides.**

Thus the compound formed by the combustion of phosphorus and chlorine is a yellowish substance, which we may call a **chloride of phosphorus**; the compound formed in like manner by the combustion of the copper is a substance known as **chloride of copper.**

We have already met with the white powder known as **chloride of lime.** It is also called **bleaching powder,** and is easily known by its powerful odour. It is largely used as a disinfectant.

In like manner **chlorine** forms compounds or **chlorides** with nearly all the elements.

If possible, one or two of the chlorides should be shown now to illustrate the kind of substance meant. Take no notice of common salt, however, just yet.

Put a small piece of **sodium** *in a deflagrating spoon, and heat it in the Bunsen burner till it is in a molten state. Place the spoon with its hot liquid metal in the third jar of chlorine.*

The sodium at once takes fire and burns with intense heat and a very bright glowing light. As the light dies down the jar will be filled with **dense white fumes.**

While these fumes are condensing in the jar, lead the class to talk about the substance that has been burnt.

It is one of the elements—the metal **sodium.** Like the other metal—potassium—it can only be kept in naphtha; why?

Take a piece out of the bottle and cut it with a knife to show its bright silvery lustre when newly cut. Notice how soon it becomes dulled, and compare it with potassium.

Lead the class to tell that as the metal **sodium** *has been burned in* **chlorine,** *the new compound formed by the combustion must be* **chloride of sodium.**

This then is the substance which has been deposited on the bottom of the jar.

Pour a little water into the jar, and let one of the class dip his finger into it and taste it. It tastes just like **salt.**

Tell that this is really **salt**—*the* **common salt** *we see and use every day. Its chemical name is* **chloride of sodium.**

Neither the gas chlorine nor the metal sodium is ever found in the pure or free state in nature. The waters of the ocean and the vast beds of rock-salt in the crust of the earth contain abundant supplies of them in this compound form—**chloride of sodium.**

Lesson XIX

CARBON

I. What it is

Show some pieces of charcoal. Call upon the children to tell what it is. Yes, the common name is **charcoal**, *but the chemist calls it* **carbon.**

Let the children examine it for themselves, and lead them to tell from their own observation that it is a light, brittle, porous black substance.

Carbon is the main basis of all **vegetable** matter. If a plant be carefully dried, so as to drive off all the water it contains, more than half of what remains will be this substance **carbon.**

Some charcoal may be easily prepared for inspection by the class. Before the commencement of the lesson take a piece of iron gas-pipe a few inches long, fill it with chips of wood, and close both ends with clay. Bore one or two holes in the clay to allow any gases to escape as they are given off; and then place the pipe in a fierce red fire for about half an hour. When it is taken out, remove the clay stoppings, and as soon as the contents of the pipe are cool enough to handle, pass them round the class for inspection.

The wood has been changed, in the pipe, into **charcoal** *or* **carbon,** *just like that which we first examined.*

Explain that the pieces of wood **have not been burned.** *If we put some similar chips on the fire, and let them burn in contact with the oxygen of the air, we shall notice that the whole of the substance will disappear, leaving nothing but a little white ash.*

By placing the wood chips in the closed pipe, within the fire, we caused the wood to decompose or separate into its constituents. Some of these passed off in the form of gases through the holes in the clay; but the carbon itself being

closed in, was not allowed to come into contact with the oxygen of the air, and was therefore not consumed.

II. How it exists in Nature

1. Carbon is, as we have already said, the chief constituent of **all plants.** We obtained it from the wood chips just now.

2. *Lead the class to tell that* **coal** *is the buried remains of the forests of far-distant ages.*

All the vegetation of those forests had **carbon** as its chief constituent. Hence the **coal** which we burn to-day consists very largely of **carbon.**

If we heat coal in a closed vessel as we did the chips of wood, we shall find this constituent, **carbon,** left behind in the form of **coke**—all the other constituents passing off as gases.

Remind the class of the little experiment with the powdered coal in the tobacco-pipe; or, better still, let it be repeated now.

Show a few lumps of white sugar, and remind the class that this sugar is really a **vegetable substance**; *it is prepared from the* **juice** *of the* **sugar-cane.**

Make a syrup of the sugar by pouring a little hot water on it; and then add a few drops of sulphuric acid to the syrup. The whole will instantly turn black and froth up to the top of the glass. In appearance this black mass resembles a piece of **coke.**

Explain that it is the **carbon** *in the* **sugar** *which the sulphuric acid has set free.*

3. Man and all animals feed directly or indirectly on plants. Hence the **carbon** of the **plant** is used to build up the **tissues of the animal.**

Explain that when the cook forgets to turn the meat which is roasting before the fire, it becomes charred or burned—the **carbon** *is made visible.*

Tell that a special kind of charcoal, known as **ivory black,** *is prepared from* **bones.**

4. Carbon forms an important constituent in **limestone** and other rocks in the crust of the earth.

The **black-lead** or **plumbago** of our lead pencils is another form of this same substance—**carbon.** It is also known as **graphite.** The name **lead** is misleading, as there is not a particle of lead in the substance.

5. The beautiful **diamond**—the most precious and brilliant of all our gems—is simply a special form of **carbon.**

III. Carbon Dioxide

In preparing our carbon in the piece of closed pipe, the great object was to shut out the air. Let us see why.

Have a jar of oxygen prepared beforehand. Place a piece of charcoal in the deflagrating spoon; heat it to redness in the flame of the Bunsen burner; and plunge it into the oxygen.

The combustion will go on with greatly increased brilliancy, showing the powerful affinity that exists between carbon and oxygen.

This is why we prepared the carbon in the closed pipe. If it had been in contact with the oxygen of the air, the whole of the substance of the wood would have been consumed.

Let the class tell that the product of the combustion in the jar is the substance they know as **carbonic acid.** *It is also known as* **carbon dioxide.**

All substances that combine in this way with oxygen form **oxides.** This is called **dioxide,** because it contains **two parts of oxygen** to **one part of carbon.** *Di* means "two."

Refer the class to their earlier lessons, and lead them to tell some of the properties of this gas.

Make a solution of blue litmus and pour it into the jar of carbon dioxide. It instantly turns to a bright wine-red colour on shaking the bottle.

Now let the mouth of the bottle be closed with the hand, and place it mouth downwards in a vessel of water.

As soon as the hand is taken away some of the water will pass up into the bottle.

Carbon dioxide is readily soluble in water. Water will dissolve its own bulk of this gas. This explains why the water rushed up into the bottle.

Lesson XX

SULPHUR

I. Properties

Show a piece of sulphur. Ask for its other name—brimstone. Lead the children to discover its properties, one by one, as far as they can by their own observation, the teacher assisting where necessary.

It is a lemon-yellow, solid body, having a faint odour, but no taste.

Tap it, and show that it is very brittle; test it, and prove that it is insoluble in water; but dissolve some of it in oil of turpentine to show that this liquid is a solvent for it.

Put a small piece on a tin plate, and apply a light to show that it is highly inflammable. Notice the peculiar pale blue flame and the suffocating odour of the burning sulphur.

Put some sulphur in a test-tube, and heat gently over the Bunsen flame. The solid substance changes into a clear yellow, limpid liquid, and as the heat is continued it becomes darker in colour, and of the consistency of treacle. It finally boils and passes off in sulphur-vapour, but before reaching the boiling point the dark mass once again becomes thin and limpid as it was at first.

While it is boiling, introduce a small coil of thin copper wire into the mouth of the tube. The metal will at once take fire in the sulphur-vapour, and burn with brilliant effect.

Compare this with the burning of bodies in oxygen.

What name do we give to those compounds which are formed when certain elements are burned in oxygen? We call them oxides.

Our experiment shows us the metallic copper burning in

a similar way in the sulphur-vapour. The product formed by that burning is known as **sulphide of copper.** Most of the metals combine with sulphur to form **sulphides.**

Show some roll-sulphur, and side by side with it some sublimed sulphur, commonly known as "**flowers of sulphur.**"

The roll-sulphur is obtained by pouring the melted sulphur into wooden moulds, and allowing it to cool.

The "flowers of sulphur" are formed by boiling ordinary sulphur, and causing the vapour from the boiling liquid to pass into a cold chamber, **where it condenses, and settles upon walls and floor in the form in which we now see it.**

Sulphur is largely used in the manufacture of gunpowder and matches, and for many other purposes.

II. How it exists in Nature

Sulphur is found **in a free state**—that is, uncombined with other substances—in Sicily, Italy, Iceland, Mexico, and more or less in all volcanic districts.

It is also found very abundantly in combination with iron and copper, **forming a sulphide known as pyrites.**

It is also met with in combination with mercury, forming a sulphide commonly called **cinnabar.** This is the chief source whence we obtain that useful metal. In one of our early lessons the method of separating the mercury from the ore was dealt with.

Most of the metallic ores are sulphides. Sulphur is frequently met with in the waters of mineral springs. The waters of Harrogate owe their medicinal value to the sulphur which they contain.

III. Sulphur Dioxide

Place a small piece of sulphur in the deflagrating spoon, set it on fire by applying a red-hot wire to it, and lower it into a jar

of oxygen prepared beforehand. It instantly bursts into a brilliant purple-blue flame, giving out intense heat, and the product of the burning is a suffocating gas. **This gas is an oxide of sulphur. We call it sulphur dioxide.** *It contains equal quantities by weight of sulphur and oxygen.*

Pour a little infusion of blue litmus into the bottle containing the sulphur dioxide. Close the mouth of the bottle with the hand, and shake briskly for a few minutes.

Before removing the hand, let the bottle be inverted in a vessel of water. When the hand is now taken away, the water will rush up into the bottle with great violence, and the blue litmus colouring-matter will have changed to a bright red.

Sulphur dioxide is very soluble in water. Water will dissolve nearly fifty times its own volume of this gas. This is why the water rushed up into the bottle.

Remind the class of the similar characteristics of carbon dioxide.

Dip the finger into the solution, and put it to the tongue. **This dissolved oxide has a sour taste.**

Lesson XXI

PHOSPHORUS

I. Properties

Show the bottle labelled phosphorus. Tell that this substance, which is another of the elements, is to be the subject of our next lesson. Call attention to the fact that this substance is always kept in water as we now see it. Presently we shall find out why.

Take one of the sticks out of the bottle, and let the class describe it as far as they can from their own observation.

It is a pale yellow, almost transparent, solid substance, resembling bees'-wax in consistency.

Dry the stick by rolling it in blotting-paper, and cut off a

piece with a knife. Press it between the fingers to show that it is capable of being moulded as well as cut. This must be done very carefully, or the heat of the hand will be sufficient to kindle the phosphorus into flame, and burn the fingers.

Call attention to the fumes of greenish-white vapour which are emitted from the phosphorus while it is being examined.

Take into a dark corner of the room, and show that it is surrounded by a bright, luminous cloud of this smoky vapour.

Contrive to have a warm plate of some kind on the table, and without entering into any explanation, place the piece of phosphorus on the plate. The phosphorus will suddenly burst into flame, and burn with a brilliant white light, giving off dense suffocating fumes of vapour.

This will illustrate **the great inflammability of phosphorus**—*its chief characteristic—and show the reason why it is always kept in water.*

As soon as the stick of phosphorus was taken out of the water small wreaths of smoky vapour began to rise from it. This was due to the rapid oxidising which takes place, even at the ordinary temperature, when phosphorus is exposed to the air. A very slight increase of warmth—**even the warmth of the hand**—would be sufficient to cause it to burst into flame. Hence great care is necessary in handling this substance. The least friction will also cause phosphorus to ignite.

Put a small piece of phosphorus (previously dried in blotting-paper) on a tin plate, together with a little powdered potassium chlorate, and strike it with a hammer. It will burst into flame, and explode with a loud bang.

It is this last property of phosphorus which makes it of such great use in the making of lucifer matches.

In one kind of lucifer the paste containing the phosphorus is put on the end of the match itself. These matches will ignite when rubbed on any rough surface, and are of course dangerous. Many accidents have happened through carelessness in using them.

In the "safety" match **the phosphorus paste is put on the box and not on the match.** There is no

danger of the match igniting until it is rubbed on the rubber.

II. How it occurs in Nature

Phosphorus is never met with in the free or uncombined state. It is chiefly found in combination with other elements, forming phosphate of lime—one of the most important materials of volcanic rocks. These are the rocks which by crumbling down produce our fertile soils.

The plants which grow in such soils absorb the phosphorus compounds from them to help in building up their own material. These plants are the food of man and animals.

All the bony structures in the animal consist largely of phosphate of lime which has been obtained in this way.

The bones owe their hardness and rigidity to the phosphate of lime which they contain.

This may be readily proved by standing a bone in dilute hydrochloric acid for a few hours. When it is taken out, the bone will be seen to have lost its firmness and rigidity—in fact, if a long rib-bone be used, it will be an easy matter to tie it in a knot or twist it into any form.

Explain that the whole of the earthy matter has been dissolved out of the bone by the hydrochloric acid, and is now in the basin. What remains of the bone is the animal material only. Call attention to the liquid in the basin. It is quite clear; we can see nothing in it.

Now pour some ammonia into it, and show that **the phosphate of lime is at once precipitated from the clear solution.**

The chemist always prepares phosphorus for his purposes from bones.

The bones are burned in a clear, open fire to a white ash. The burning gets rid of all the animal matter of the bone; **the white ash left behind is the earthy or mineral matter,** and is known as bone-earth or bone-ash. It is this bone-earth which yields the phosphorus.

The method of treating it for this purpose is too complicated to concern us now.

III. Phosphorus Oxide

Cut a small piece of phosphorus, and after thoroughly drying it in blotting-paper, place it on a stoneware or metal dish, light it, and cover it with a bell-jar. Care must be taken to see that the bell-jar and dish are quite dry.

As the combustion goes on, raise the jar a little from time to time to admit more air. Explain that the burning phosphorus is rapidly robbing the air in the bell-jar of its oxygen, and this is why we continue to admit more air. We want the whole of the phosphorus to be consumed.

When the combustion ceases, the dense fumes which fill the bell-jar will begin to condense and fall on the plate as a soft, white, snow-like powder. **This powder is an oxide of phosphorus.** *It was formed by the combination of phosphorus and oxygen. Remove the bell-jar, and pour a few drops of water into the dish. Notice the violent hissing sound that follows.*

Explain that this oxide of phosphorus has a powerful affinity for water; it was the energy with which the water sucked up the white powder that caused the hissing.

Add a little blue litmus solution, and show that the effect is the same as we have seen before in the case of the oxides of carbon and sulphur. **The blue litmus has turned red.**

Dip the finger in the dish, and put it to the tongue. **This dissolved oxide, again, has a sour taste.**

Lesson XXII

ACIDS

I. Nature of an Acid

Show some spirit of salt. Tell its name, and speak of its uses as a cleansing agent. It is used for many household purposes.

Pour a little into a test-tube, and add a few drops of

litmus solution. **The colour is instantly changed to red.**

Lead the class to tell that we have already met with this same characteristic in the dissolved oxides which we examined. They all turned blue litmus red.

Let one of the class dip his finger into the liquid and put it to his tongue. **It has a sharp, strong, sour taste.**

This too we have met with before. We found the dissolved oxides of sulphur and phosphorus to have a very sharp, sour taste. The carbon dioxide solution is sour too, but only very slightly. There are many substances besides those we have examined which have the same characteristics.

The chemist has one name for all of them. He calls them acids.

Explain that in ordinary language the word "acid" means "sour." It comes from a Latin word **acidus,** *"sharp" or "sour," and the word itself calls up in our mind the sharp, sour taste of vinegar or of unripe fruit.*

Many substances possess this peculiar sharp taste, and when the name "acid" was first used by the chemist, it was limited to such bodies. They all have the same effect too, in turning blue litmus red.

But we now know that although most acids are sour to the taste, there are some which are not. To the chemist, therefore, this sourness is a mere accident.

Acids are now distinguished entirely by their action on vegetable colouring matter.

Any substance which can change litmus which is naturally blue to a red colour is an acid, whether it be sour to the taste or not.

We are now in a position to give their proper names to those substances which we have till now spoken of as dissolved oxides.

Carbon dioxide, when dissolved in water, is **carbonic acid.**

Sulphur dioxide when dissolved in water is **sulphurous acid.**

The oxide of phosphorus which we produced and examined became, when it was dissolved in water, **phosphoric acid.**

These acids and many more like them were produced by the combustion of some body in oxygen.

There are other acids which are not formed in this way, and these are not oxides, they contain no oxygen at all.

The spirit of salt which we examined just now is one of them. It is also known as muriatic acid and hydrochloric acid.

Lead the class to see, from the name, that this **hydrochloric acid** *is formed of two bodies which our lessons have made familiar to us*—**hydrogen and chlorine.**

II. Hydrochloric Acid

Show two or three jars of the gas. The mode of preparation is easy, but to save the time of the class the gas may be prepared beforehand if desirable.

Take equal weights of common salt and sulphuric acid.

Explain that this is not the sulphurous acid with which we are now familiar, but another very powerful acid, formed of sulphur, oxygen, and water.

Show some, and let the class test it to prove by experiment that it has **a powerful sharp taste,** *and* **turns blue litmus red.** *Its common name is oil of vitriol.*

First fuse the salt in an iron ladle over a very fierce red fire, and after the mass has cooled, break it up into pieces. This is a precaution against the too rapid and violent action that would take place if the sulphuric acid were poured upon the powdered salt. By fusing and breaking the salt into pieces, there is less surface of salt for the acid to act upon, and the evolution of the gas is more gentle, and the flow more regular.

Put the pieces of fused salt into a flask, and add enough sulphuric acid to cover them.

As soon as action commences, apply gentle heat to the flask, and the gas (hydrochloric acid) will be rapidly evolved.

As hydrochloric acid is heavier than air, it can be collected in the jars **by downward displacement.** *Stand the jars with their mouths open, and let the delivery-tubes dip into them. The hydrochloric acid will fill the jars and drive out the air from the top.*

It will be easy to see when the jars are full, as the moment the gas begins to overflow and come in contact with the air, fumes will be seen round the mouth of the jar.

The jars may now be closed with the glass plates, and the gas will be ready for experiment.

1. *Take one of the jars, with the glass plate still closing the mouth, and invert it in a vessel of water. Slide off the glass plate beneath the surface, and the water will rapidly rush up and fill the jar, dissolving the gas which it contains.*

There is very strong affinity between this gas (hydrochloric acid) and water. **Water will greedily dissolve 480 times its own bulk of this gas.**

The spirit of salt (muriatic acid) is hydrochloric acid solution, *i.e.* hydrochloric acid dissolved in water.

The reason for the name (spirit of salt) may now be given. The gas was prepared from common salt.

2. *With another jar of the hydrochloric acid perform a similar experiment in a vessel of water previously coloured with blue litmus. The blue water will be seen to turn red as it rushes up into the jar of the gas.*

Let the class explain this.

Lesson XXIII

BASES, ALKALIES, SALTS

I. Nature of a Base

Fill a shallow bowl or dish with water previously coloured with red cabbage infusion. Throw on the surface of the water a piece of the metal potassium.

Explain that this metal is very similar to another which our

lessons have made familiar to us. It oxidises very rapidly, and for that reason has to be kept bottled up in naphtha. It cuts easily with a knife, and the newly-cut surface has a lustrous appearance.

What is the name of the other metal of similar properties? The other metal is sodium.

Our potassium is very light—lighter than water. Hence it floats about on the surface. **It takes fire spontaneously, and burns, as it floats, with a beautiful purple flame.**

Explain this spontaneous combustion by describing the powerful affinity potassium has for oxygen. It burns by robbing the water of its oxygen.

But what else do we see? The reddened water in the bowl has changed into a bluish-green while this burning has been going on.

The fact is, the potassium has been combining with the oxygen of the water and some of its hydrogen to form a new substance, which the chemist calls **potassium hydrate,** but which we shall call by its common name **potash.**

This substance is in the water although we cannot see it. Its presence is shown **by the change of colour in the water.**

Potash is prepared for various purposes in a different way from this; and when so prepared is obtained in the solid form.

Show some sticks of the solid substance. Explain that it has to be kept in closely-stoppered bottles because of its greedy affinity for water. If left open, it would absorb moisture from the air, and run away in a liquid.

If, then, I put some of it into water, what will happen? It will rapidly dissolve in the water.

Make a solution of the potash. Dilute a little of it in a test-tube, and let one of the boys dip his finger into it and taste it. It has an **intensely acrid taste**—*a taste like that of common washing soda; and possesses* **strong caustic** (*burning*) **properties.** *It is known as caustic potash.*

Put into a test-tube some litmus previously reddened by an

acid, and pour some of the potash solution into it. **The original blue colour of litmus is instantly restored.**

Here, then, we have a substance — potash — distinguished by—

1. Its peculiar acrid and caustic taste, resembling that of common washing soda.
2. Its power of changing vegetable reds to blue or green.

This substance is only a sample of a great many bodies possessing similar properties. They are mostly oxides, but they are the oxides of certain metals.

Remind the class that potassium is a metal. The other metal, sodium, would have acted in a similar way if thrown on the water, except that it would not have burst into active flame. We took potassium as it is a more interesting experiment.

The chemist has one general name for all bodies which possess the properties which we have found in potash.

Any substance which has an acrid taste, and is able to change vegetable red to blue, he calls a **base.**

There are besides a number of **insoluble bases which have no taste, and no effect on litmus,** but we shall not deal with these here.

II. Alkalies

Many of the bases resemble caustic potash in being soluble in water. These have another name. They are called **alkalies.**

That is to say, an alkali is a base of a special kind. It is soluble in water, and it gives the water a soapy taste and feel.

Pour into a large test-tube some olive-oil, and add to it some of the solution of potash. Shake the mixture for a few minutes, and call attention to the thick, semi-transparent, soapy liquid which is formed.

Let some of it be poured into the palm of the hand, and call upon the children to describe its soft, soapy feel. **We have**

made soap. *This experiment illustrates one of the chief uses of the alkalies—as important ingredients in the manufacture of soap.*

III. Salts

Show the class the bottle of nitric acid. Tell its name, and explain that it is one of the most powerful of the acids.

Let the class note its peculiar odour. Make a very weak solution, and have it tested for taste. It has a very **sour taste.**

By spilling a drop of the acid on the fingers, show its powerful corrosive action. It rapidly destroys animal tissues, and stains the skin a bright yellow.

Put a little of the dilute acid in a test-tube, and dip into it some blue litmus-paper. The colour is instantly **changed to a bright red.** *Here we have all the characteristics of* **an acid.**

Now make a solution of caustic potash, and dip the reddened litmus-paper into it. **The blue colour of the litmus is at once restored.**

Lead the class to tell that this last experiment proves the solution to be **a base.**

Explain that it is really a base; it is a solution of the alkali caustic potash, which we have already examined.

Now mix the two together, and dip another piece of blue litmus-paper into it. **There is no change in colour.** *The acid property has disappeared.*

If red litmus be tried next, the result will be the same. The liquid is now neither an acid nor a base. **It is neutral to both blue and red litmus.**

If a little of the liquid be poured on a watch-glass, and allowed to evaporate, crystals of the new body will be left covering the surface of the glass.

This substance—the product of an acid and a base—is called **a salt.** The name of this particular salt is nitre or saltpetre.

Let the class taste it and compare it with a piece of ordinary saltpetre.

LESSONS FROM PHYSIOLOGY

Lesson XXIV

THE BLOOD AND ITS WORK

I. Work and Waste

The body is a sort of living machine. Some part or other of it is always at work, night and day, sleeping and waking. Think of a person asleep. What work is going on in his body even while he sleeps?

Lead the children to see that the brain, heart, and lungs are never at rest.

All bodily work is done at the expense of the substance of the body itself. Every act of our daily life, the movement even of a little finger, the flashing of a single thought through the brain, or the blinking of an eyelid, destroys some of the substance of the body.

Think of a steam-engine at work. It is the fuel in its furnace and the water in its boiler that enable it to perform its work; **but the living machine works at the expense of its own substance.**

Each little particle of brain, nerve, muscle, skin, having once performed a certain work, becomes henceforth worn-out, dead matter. **Our body lives by dying.** Some part of the body is dying every moment.

II. The Blood

Lead the children to tell that, notwithstanding this constant destruction of the substance of the body, a person in good health varies very little in size and weight for years. Boys and girls, in fact, are daily growing bigger.

The reason for this is that all over the body there is

not only waste, but renewal going on. Bit by bit, every part of the body—muscle, brain, bone—is not only being destroyed by work done, but as it is destroyed it is renewed or **built up again** in its original form.

What do you think does this building-up work? The blood.

If I prick myself in any part of my body, blood will flow out. There is blood all over the body. It is this **blood which builds up what has been worn out.** It carries all the materials for building the various tissues.

To the muscles it gives certain particular materials for making muscle; to the bones it gives up other materials for making bone; in the brain and nerves it leaves other materials again for making nerve-matter, and so on. But it never leaves bone-making materials for building up muscle, brain, or nerve; nor does it take to the ear what is wanted for the eye. It never makes mistakes.

III. The Blood circulates

We know that there is blood all over the body. But this blood does not stand in the body as water stands in a bottle; neither is it still and stagnant.

It is a restless stream, **incessantly on the move,** bringing to every part the materials required for building purposes, and carrying away whatever is no longer wanted there.

Lead the children to tell what would happen if this stream were to cease to flow. The body would suffer in two ways. It would become choked up with the accumulation of waste matter, and at the same time it would be starved for want of new material.

Therefore, as long as life lasts, **this stream of the blood must flow on.**

We say that the blood **circulates.** We mean to say by this that it does not merely pass through the body like a stream and disappear, but is carried round and round, over and over again.

one direction—from the smaller into the larger trunks, and so on to the heart.

We cannot see the blood flowing along our veins, but the fact may be clearly shown, with the aid of a microscope, in the transparent web between the toes of a frog.

The veins, as seen just beneath the skin, have **a dark purple colour.** The blood which is coursing along them towards the heart is not bright red blood, such as we usually see, but **purple—almost black.** It is in fact loaded with impurities.

How did these things find their way into the blood?

Tell that they are the waste dead matter—the worn-out particles of muscle, nerve, brain, bone, etc., which the blood in its course has caught up and carried away.

These waste matters could not be allowed to remain in the body. They would be very injurious. They have changed both the character and appearance of the blood. It was bright red blood before; now it is dark purple, and impure.

Compare them with a heap of rotting, putrefying refuse matter, and tell of the mischief it would cause.

It is the duty of the veins **to collect up** all this impure blood, and **pass it along** through larger and larger trunks, and finally **to discharge it into the heart.**

Tie a cord tightly round the finger, and note that the finger soon becomes swollen and purple.

Why is this? The veins leading upwards from the finger lie near the surface of the skin, and have been closed by the pressure of the cord. The consequence is that the blood cannot flow through them, and so onward towards the arm, but remains where it is, giving the vessels a swollen or congested appearance.

II. The Arteries

These vessels carry blood from the heart into all parts of the body. Their great main trunk, which springs direct from the heart, is a pipe rather larger than one's

thumb. This sends off branch after branch, each branch dividing again and again into smaller and smaller ones still, till they are as fine as the finest veins.

But the blood which passes along this channel, and so on to the smallest arteries, is good blood, free from impurities, and loaded with materials for renewing those parts of the body which have been worn out. **It is a bright red colour.**

Illustrate by reference to the water-supply of a large town—the pumping station with its great main, the pipes running from this under the roadways, the smaller branching pipes under the streets, and finally the delivery pipes in connection with the individual houses. The pipes bring pure, wholesome water to the houses. This water, after performing its office, finds its way, contaminated with filth and all sorts of impurities, to the drain. The drains from the various houses run into larger pipes, and these into still larger, until the great main sewers are reached, and these carry the stream far away from the town, and empty it into the sea—the great purifier. Evaporation carries the pure water-vapour upwards to form clouds; condensation of the clouds deposits it again on the earth as rain; the rain forms springs and rivers, which again supply the water company's mains—and so the circulation is complete.

Compare arteries, capillaries, veins, lungs, and heart.

The arteries are usually deeply embedded in the flesh, and cannot be seen; and this is not a mere accident, but really a wise provision against injury.

If a vein is cut or injured, it is comparatively **easy to close up the wound and stop the bleeding**; but this cannot be done so easily with an artery, and the person is in extreme danger of bleeding to death. Hence the wisdom of packing away the arteries deep in the flesh.

If an artery were removed from the body of any animal and examined, it would be found to be a plain, simple pipe, through which water might be poured from either end.

If a vein were removed, however, and treated similarly, we should find it easy enough to pour water through from one end, but when we tried to do so from the opposite

end, the **pipe would become closed or stopped up** in some way.

By cutting the two pipes open we should discover the reason for the stoppage. The veins every here and there are provided with **little bags or pouches of skin,** which stretch across the vessel and have their mouths or openings **all turned one way,** *i.e.* towards the heart.

Draw on the black-board a sketch of the vein cut open, with its little pouches or bags seen.

Tell that these bags form **valves.** *Ask the class to tell the object of valves, and how they act. Refer to the valves in pumps, and show that whatever the construction, the purpose is always the same.*

In the veins **the valves** allow the blood to flow past them on its way to the heart; but should it, from any cause, attempt to flow backwards, it would fill the little pockets and swell them out till they blocked up the way altogether. There are no valves in the arteries.

III. The Capillaries

In every part of the body there must be these two sets of vessels—**arteries to bring fresh pure blood; veins to carry it back to the heart contaminated with impurities.** Every artery ends and every vein commences in a network of smaller hair-like capillaries. So close are these tiny vessels placed, that it is impossible to prick the skin anywhere without piercing the walls of some of them, and causing the blood to flow.

The walls of the arteries are **stout and muscular**; those of the veins are **thinner and somewhat flabby**; but the capillaries have the **thinnest of thin walls**—they are extremely thin and delicate.

The complete round of the circulation from the heart, along the arteries, through the capillaries, and back by the veins to the heart again is accomplished in about half a minute.

Lesson XXVI

THE HEART

Introduce the new lesson by calling upon the class to tell all they know of the blood and its work, and of the way in which it circulates through the body. We have said that the centre or mainspring of this circulation is the heart. We are now going to learn something about this important organ.

I. Situation

The heart is situated in the middle of the thorax or chest, between the two lungs, and in a slanting position. [*Show a sheep's heart.*] It is pear-shaped, and has its broad end or base turned upwards and backwards towards the spine, and its pointed end or apex turned downwards, forwards, and to the left.

Explain that between the fifth and sixth ribs, and on the left side of the chest, one may feel with the hand a certain movement which we commonly call the beating of the heart. This is caused by the apex of the heart striking on the front wall of the chest at this point. Hence the common mistake of supposing the heart to be at the left side of the chest.

II. Description of the Heart

The heart is a hollow organ, made entirely of muscle. It is about the size of one's closed fist. It contains two great chambers, completely separated from each other by an immovable wall or partition of muscle, which reaches from the base to the apex.

Each of these great chambers is further subdivided by another partition, stretching crosswise. Thus the heart really contains four chambers of the same size—two upper, and two lower.

The upper chambers are called the **right and left auricles**; the lower, the **right and left ventricles.**

The heart is really a double organ, consisting of two complete hearts.

There is a passage between the upper and lower chamber on each side, so that whatever is in the auricle can pass through into the ventricle below; but there is no direct communication between the right and left sides of the heart.

Make a diagram on the black-board showing these four chambers of the heart.

III. The Heart a Muscular Organ

Lead the children to explain what is meant by the working of a muscle—a muscle works by contracting, and directly the contraction is over it springs back to its original size.

The muscles of which the heart is formed always work in one particular way. **The auricles and ventricles are never at work together.**

Both auricles begin to contract at the same moment, but this is only the signal for the ventricles to cease working; and when the ventricles in their turn begin to contract, the auricles cease work.

In this way, at the very moment when the two ventricles are contracted to their smallest size, the two auricles are expanded or stretched out to their fullest extent. When the auricles take their turn to work (or contract), the ventricles, in like manner, expand to their fullest size.

Your heart has never ceased to work in this way since you were born, and never will cease till you die.

It is by this alternate contraction of auricles and ventricles that the heart does its pumping. Every time the **auricles** contract, they force the blood that is in them through the passage in their floor into the ventricles below.

Illustrate again with the hollow india-rubber ball and some water.

The blood once in the ventricles must not be allowed to flow back into the auricles again.

Can you think of any way of preventing it? A valve would prevent it from flowing back.

There is a valve in the passage which leads from the auricle to the ventricle on each side of the heart.

Let the children tell again the general purpose of a valve. It will not be necessary to enter too deeply into the structure of these. See that it is clearly understood that these valves open downwards into the ventricles.

When the auricles contract, the way through the passage lies open, and the blood passes from the auricles into the ventricles, and fills them.

When the ventricles in their turn contract, these valves close together and block up the way, so that the blood cannot return into the auricles again.

Lesson XXVII

[*The Dissection or not at the Teacher's discretion.*]

THE GREAT BLOOD-VESSELS OF THE HEART

It will be well to deal with the rest of the subject by making a simple dissection of the sheep's heart. Let the heart be first handed round the class, drawing attention to what can be seen from the outside—e.g. *the base, apex, right and left auricles, and the position of the two ventricles, as shown by the line of fat which crosses the heart in a slanting direction.*

We have spoken about blood in the auricles. But how did it get there? We said too that the great valves prevent the blood from flowing back into the auricles when the ventricles contract. But the contraction of the ventricles must force the blood somewhere. Let us see.

Commence the work of dissecting by finding and showing the two great **venæ cavæ,** *opening into the right auricle.*

Tell that these are the two main streams which receive the blood from all the veins of the body.

What kind of blood do these veins bring to the heart?

Now slit up these vessels with the scissors, and show that they both open into the right auricle. The **Eustachian valve,** *guarding the entrance of the* **inferior vena cava,** *may, or may not, be noted, according to time and circumstances.*

Call attention to the clots of dark purple blood in the auricle.

The two great veins, then, bring the impure blood back to the heart, and open into the right auricle.

Now cut away the walls of this auricle. They are very thin. Point out the orifice in the floor of the auricle (large enough to put two or three fingers through). Make the class tell what it is.

Pour some water through it into the ventricle, and as the water fills the chamber, show the flaps of the valve, floating on the top of the water, and fitting together edge to edge, completely blocking the way.

Tell that at first these flaps hung down into the ventricle. As we filled the ventricle with water the flaps rose up and blocked the way. In the living body the action of these flaps is much the same. When the ventricle has finished its contraction, and is empty, the flaps of the valves hang down, to leave the way open for the blood to fill it again; and as it fills, the flaps rise to close the entrance in readiness for the next contraction.

Now lay open the right ventricle by slitting it down the front. Call attention to the stoutness of the walls of this chamber.

It has more work to do than the auricle—**its muscles are thicker and stronger.**

Next pass a pencil up towards the top of the ventricle, and find the opening of another great vessel. Tell that this vessel (the pulmonary artery) receives the blood from the contracting ventricle, and carries it, **still in its purple, impure state,** *away to the lungs.*

Tell the reason for the name. Slit the artery open, and point out the semi-lunar valve which guards the passage.

The blood once in the artery must not flow backwards;

it must still go forward. The valve prevents it from flowing back into the ventricle.

Remind the class that **both chambers on the right side of the heart contain purple or impure blood.**

All the right side of the organ may be removed now by cutting through the partition wall.

Now find, hidden away among the fat that covers the base of the heart, the mouths of the four tubes (pulmonary veins). Note the difference between the flabby walls of these vessels and the stout muscular walls of the pulmonary artery.

Tell that these vessels have come from the lungs—that they bring to the heart blood which has been cleansed and purified in the lungs.

Slit them up, and show that they open into the left upper chamber—the left auricle.

Proceed with this chamber as we did with the right auricle, and show the great valve leading from it into the left ventricle below.

Lastly lay open this chamber, and find, leading from its upper part, the great artery (aorta) which carries blood out from the heart to all parts of the body. This, like all the blood on the left side of the heart, is pure bright scarlet blood.

Note the thickness of the walls of this ventricle, and the stoutness of the great artery. This points to the hard pumping work which has to be done by the left ventricle.

Close the lesson by following a quantity of blood, first, from the aorta to the great vena cava, and then from the vena cava to the aorta again.

Lesson XXVIII

OXIDATION

I. Arterial and Venous Blood

Commence the new lesson by leading the class to tell all they know of the connection between work and waste in the body.

Wherever work is going on there must be waste, and the waste matter must not be allowed to accumulate. It would poison the whole system.

We have learned that these waste, poisonous matters are removed by the blood. But how are they removed? This is what we have next to learn.

Call upon the children to tell (as far as they know at present) the difference between arterial and venous blood.

The dark purple blood in the veins was less than a minute before flowing through the arteries as bright red arterial blood. The blood sent out of the right ventricle of the heart to the lungs by the pulmonary artery is **the same dark purple fluid.** It is purple because it is loaded with impurities which it has taken up in its course through the body.

How does that same blood return to the heart again? It is brought back to the left auricle of the heart by the pulmonary veins—**bright red arterial blood.** It has been cleansed from its impurities while passing through the lungs. But it has not only given up its poisonous impurities, it has taken in something in the lungs which is very necessary to our existence.

The pulmonary veins are the only veins containing pure blood, whilst the pulmonary artery is the only one containing impure blood.

II. Oxygen, the Burner

Lead the class to talk next of the composition of the air. Make them tell that oxygen forms one-fifth of the bulk of all the air around us, and that the chief property of this gas is its power of burning or oxidising other substances.

Refer to one or two of the experiments shown in the former lessons.

Suppose I placed a piece of burning candle in a jar of oxygen, what would happen? It would burn rapidly with a very brilliant glow.

How long would it burn? Till all the oxygen was consumed.

And what would become of the substance of the candle itself? It would disappear.

How does it disappear? The oxygen burns the carbon and hydrogen of which the candle is made, and converts these into the form of gas—carbonic acid and water-vapour.

The smoke which rises up the chimney is very different in appearance from the lump of coal burning in the grate, yet it contains all the substance of the coal itself, converted into another form by the oxygen of the air.

Burning is merely a change—nothing is lost—there is no destruction.

III. How the Waste is removed

Now let us see what all this has to do with getting rid of waste matters from the body.

The solid particles of brain, muscle, or other tissue, although they have by their work become worn-out and waste matter, cannot be carried away out of the body in that state. They must undergo a complete change into new and totally different substances. This change is brought about by the gas oxygen.

Throughout life the work of breathing never ceases. This work is twofold. We **exhale**, or send out; and we **inhale**, or breathe in.

That which we inhale is pure air, and one-fifth of it is the gas oxygen. The oxygen thus taken in as we breathe is absorbed into the blood in the lungs, and carried into all parts of the body.

Wherever the oxygen meets with tissues which have been used up or worn out by their work, it seizes upon them, and **a slow burning or combustion** at once commences.

The harder we work the faster our tissues are destroyed,

and the quicker must we breathe in order to take in oxygen to burn them up. This constant burning up of the waste matters by oxygen in all parts of the body keeps us warm.

When we are in bad health, and the blood does not circulate freely, we are always cold. There is not enough oxygen sent through the body at such times to do the necessary work of burning or oxidising the waste matters.

Be careful to convey a clear idea of this burning in the body. The various substances burning in the oxygen have left the impression of a brilliant flame and intense heat, and ordinary observation associates blaze and smoke with all burning. The oxidation which goes on in the body is quite distinct from all this.

The best way to illustrate it is by referring to a gardener's hot-bed. Show that in this case the heat is caused by slow oxidation of the heap of leaves or manure.

IV. Products of the Burning

What happens when we have been undergoing some unusual exercise? We breathe more rapidly; the heart beats at a quicker rate; and we feel the blood coursing through the body.

Why is this? More of the tissues than usual have been used up and become waste matter, and more oxygen must be taken in and carried to them by the blood to burn them up. The increased burning makes us feel warmer after exercise.

What do you notice about the skin at such a time? It is covered with moisture. Moisture oozes out from the skin—we sweat or perspire.

Breathe on a slate or some polished surface. Show that our breath contains moisture too.

What do you think this water is?

Tell that the water is one of the products of the burning up of the tissues.

Lead the class to tell of the composition of water. Water is always formed when hydrogen burns.

Hence we learn that hydrogen is one of the materials of which our bodies are made.

Let one of the class breathe through a piece of tube into a glass of lime-water.

Show the gradual change that takes place, and make the class explain that the change is due to the presence of carbonic acid in the breath.

Make them tell the composition of this gas, and lead up to the fact that carbon enters largely into the constituent materials of the body.

These two substances—carbonic acid and water—are being constantly formed by the burning up of the carbon and hydrogen in the body. There are other products of the burning—one in particular, ammonia; but carbonic acid and water are the chief.

The blood, as it courses through the body, absorbs these products of the burning, and they change its character from a life-giving to a poisonous stream. It becomes dark purple in colour, and is carried in this state by the veins back to the heart and so on into the lungs. There it gives off carbonic acid and water, and takes in pure oxygen in their place. It is this exchange which reconverts the venous into arterial life-giving blood once more.

Lesson XXIX

RESPIRATION—THE LUNGS

Lead the class to recapitulate the main facts taught last lesson. Then tell of the oxidation of the worn-out tissue, the absorption of the products of the oxidation into the blood, and the consequent change in its character. Let them follow it as it is collected up by the veins and carried to the heart and then on to the lungs to be purified.

Our next business will be to learn something about the lungs themselves.

I. Situation, Size, and General Appearance

The lungs are the two large organs which surround the heart. As they take up the whole of the space in the thorax not occupied by the heart, they have the conical shape of that chamber.

See that the class have a clear conception of the thorax.

It is a beehive-shaped box, formed by the spinal column, the ribs, and the sternum, and has a movable floor —a thick strong flat muscle—the diaphragm.

This conical box is air-tight.

The lungs are soft, spongy, elastic, and of a pinkish-grey colour. They are securely attached both to the diaphragm (the floor) and also to the inner walls of the thorax. There is absolutely no space between them and the walls of the chamber in which they work.

The consequence is that when the walls of the thorax move, and so enlarge or diminish the size of the chamber, **the lungs must expand or contract with them,** as the case may be, in order to accommodate themselves to the space provided.

Refer to the lesson on the bony skeleton, and lead the class to tell that the ribs are attached to the vertebral column in such a way as to be capable of moving up and down.

How is it that this up-and-down movement of the ribs has the effect of enlarging and diminishing the size of the chamber.

Show that it is due to the slanting position of the ribs.

II. Air-Passages of the Lungs

The back of the mouth and the nasal passages open into a large cavity, the pharynx, and from the lower part of this a long stout tube, the **windpipe,** extends downwards into the chest.

This pipe, which is formed of stout rings of gristle, can be felt. The rings make it hard and resisting to the touch, and prevent it from collapsing with pressure.

After entering the chest, the windpipe branches into two—the bronchi; **one bronchus going to the right, the other to the left lung.**

In the lungs these bronchi divide and subdivide again and again, forming bronchial tubes, and end at last in extremely fine branches which spread themselves all through the substance of the organ. In fact they actually form the substance of the lung itself, for each bronchial tube ends at last in a bunch of little hollow, elastic bladders, called **air-cells**; and it is the mass of these air-cells which make up the entire lung.

Picture to the class a bush crowded with leaves. Imagine it hollow throughout—stem, branches, twigs, and all. If they could but think of the leaves themselves as little elastic bladders at the ends of the tiniest of these hollow twigs, they would have a fair conception of the arrangement of the air-passages and air-cells in the lungs.

Let the children trace the course of the air, as it is inhaled, through windpipe, bronchus, and bronchial tubes, which are continually becoming smaller and smaller, until it reaches the air-cells of the lungs.

These air-cells are elastic. Why? Tell that the whole lung expands to receive more air, or contracts to drive air out, **only because each little air-cell itself is elastic** and has the power of expanding and contracting.

III. Blood-vessels of the Lungs

The pulmonary artery, after leaving the right ventricle of the heart, divides into two branches—one for each lung. In the lung each branch divides again and again, until at last it forms the most delicate capillaries.

These capillaries spread themselves through every nook and corner of the substance of the lung.

But the substance of the lung is really the thin delicate bladder-like wall of the air-cells, and it is round these little air-cells that the finest branches of the pulmonary capillaries spread themselves.

These little vessels, like all other capillaries, eventually reunite and form the commencement of tiny veinlets; and they in their turn continue to do the same, until at length they leave the lungs by four main pipes, the pulmonary veins (two from each), and proceed to the left auricle of the heart.

Lead the class to tell that the blood in these pulmonary capillaries is dark purple venous blood, loaded with carbonic acid and other impurities.

In these delicate vessels it is separated from the air in the air-cells by the finest possible membrane. We want to learn now how the exchange takes place, how the oxygen from the air in the air-cells passes through into the blood, and how the carbonic acid from the blood finds its way into the air-cells in place of it.

IV. Osmosis

Take a glass funnel with a wide mouth and a long slender stem or tube, and bind a piece of thin bladder firmly over the mouth, so as to make it water-tight. After seeing that the bladder is properly adjusted, fill the funnel and part of the stem with either a solution of sugar or some dense saline solution.

Hold it up and show that none of the liquid escapes, because the bladder at the bottom has been firmly secured.

Now place the funnel in a large vessel of water, so that the liquid within the tube and the water outside it are at the same level.

The liquid will be seen to rise gradually in the tube until at length it actually runs over the top, evidently showing that some of the water from the outer vessel has entered the funnel.

One of the best liquids for this experiment is a solution of bluestone (sulphate of copper), because it can be plainly seen as it rises in the tube, while at the same time the outside water

gradually assumes a blue tint, and the whole of the story becomes plain to all, viz. that there is a double exchange going on—water is passing through the bladder into the funnel from outside, and at the same time some of the liquid is passing out of the funnel into the clear water.

Osmosis is the name given to this passage of the fluids through the membrane.

This is the very work that is going on in the lungs. It is in this way that the blood gives up its carbonic acid and takes in oxygen. **Both gases pass through the actual membrane which separates them.**

Lesson XXX

THE WORK OF BREATHING

Introduce the new lesson by making the class tell the structure of the lungs, with their air-cells and extremely fine blood capillaries. Let them explain the constant exchange going on by **osmosis** *through the delicate dividing walls.*

What would be the result if the air in both cells and air-passages were not constantly renewed? The air in these would in a short time be deprived of all its oxygen, and become completely saturated with carbonic acid.

This is why the work of breathing never stops—sleeping or waking. The impure vitiated air must be driven out, and pure air taken into the lungs to supply its place.

I. Breathing

A healthy man resting calmly in a sitting position breathes from 13 to 15 times every minute; but as soon as he begins to exert himself with exercise of any kind, the breathing becomes more rapid, and continues to increase in rapidity in proportion to the exertion he makes.

Each breathing consists of three distinct acts following

each other in regular order. First a quantity of air is drawn in, this is called an **inspiration** (*i.e.* a breathing in).

As soon as the inspiration is over the second act commences, and the air is driven out or expelled from the mouth and nostrils. This we call an **expiration** (or breathing out).

Show the meaning of these words.

Then comes a pause; after which the same process is perpetually repeated, and always in the same order—inspiration, expiration, pause—like some very beautiful piece of machinery.

The mechanical work of breathing is due to three causes—the pressure of the atmosphere, the elastic nature of the lungs themselves, and the character of the air-tight box (the thorax) which contains them.

II. The Pressure of the Atmosphere

This will form a good opportunity for leading the children to tell all they can remember of this interesting subject. After the leading facts have been elicited, proceed in some such way as this to apply them to the work of breathing.

The thorax is perfectly air-tight; no air can get in between the lungs and the outer walls of this chamber. Air, however, does enter the lungs themselves through the windpipe and air-passages, and it presses with a force of nearly 15 lbs. on every square inch. This enormous pressure from within the lungs **forces them outwards against the sides of the chest.**

The chest itself is protected by a hard resisting bony cage, and not by soft flabby walls; so that although the outer air is pressing with the same force it cannot squeeze that chamber nor affect the lungs inside.

The lungs therefore are pressed outwards against the walls of the chest by the air within them, but they feel no pressure from without.

III. The Elastic Nature of the Lungs

The air-cells are elastic. They are made of extremely elastic fibre, so arranged as to be capable of stretching when the cells are full of air. The cells are then stretched to their fullest extent, each time they fill with air.

But the elasticity of the cell-walls immediately afterwards asserts its power by contracting, and so drives out most of the air again.

IV. The Thorax

The ribs, which form the walls of this chamber, can be raised and depressed.

Tell that this is done by two sets of muscles between the ribs —one set to raise, the other to depress them.

The diaphragm, which forms the floor of the chamber, is also capable of moving up and down. What would be the effect of such movements?

This diaphragm is a muscle, and, like all other muscles, possesses the power of contracting. When it contracts it pulls the floor of the chamber down, and it always does this just when the ribs are being raised. What is the effect of these combined movements?

Take, if possible, a recently killed rabbit, open the abdomen, and carefully remove the whole of its contents, leaving the cavity quite empty. Now let the class examine the diaphragm. They will find that it is thin and transparent near the middle, and that the pinkish lungs can be seen on the other side.

Notice next the hollow, arched shape of the diaphragm. Take hold of it firmly but carefully in the middle, and pull it down into the abdomen; and so show that it forms a movable floor for the chest.

But what happens when we pull the diaphragm down? The lungs come with it.

Show that this is not done by dragging them away from the

top and sides of the thorax, for they still remain firmly attached all round.

The lungs, being elastic, swell up so as to fill the extra room made in the chest.

When we let go the diaphragm it springs back again to its former arched position, and the lungs are squeezed into the smaller space.

That is to say, when the diaphragm is arched up, so that the cavity of the thorax is small, **the lungs fill the cavity**; and when the diaphragm is pulled down and the chest is enlarged, the lungs swell out, **and so still fill it.**

They could not do this unless they were made of very elastic tissue.

If now a small pin-hole be made in the diaphragm, a peculiar sucking sound will be heard, and the lungs will be seen to shrink up into a very small bulk at the back part of the thorax.

The diaphragm may now be pulled up and down without affecting the lungs in the least. They still remain shrunk up at the top of the chest.

Tell that in the natural state, while the chest remains an air-tight chamber, the lung lies so close to the walls and floor of the chest that there is practically no space between them.

As soon as the hole was made in the diaphragm, however, the air rushed in, and so pressed on the outside of the lungs.

The lungs were kept distended only by the pressure of the air from within down the windpipe; the natural tendency of their elastic walls being to pull against this pressure.

When therefore this elasticity of the lungs was suddenly assisted by air-pressure from without, as it was when we pricked the diaphragm, the only result possible was the collapse of the organs.

From these facts proceed to explain the mechanism of breathing.

The contraction of the diaphragm and the raising of the ribs enlarges the chest; the elasticity of the lungs enables

them to stretch out to fill the larger space; the air rushes in down the windpipe to fill all the little distended air-cells, or there would otherwise be a vacuum. We have the explanation of an **inspiration.**

Immediately after this, the diaphragm expands and rises, and the ribs are pulled down; the lungs assert their power by contracting; and every little air-cell is squeezed into smaller space, with the result that some of the air in them is then driven out. Thus we explain an **expiration.**

Lesson XXXI

WASTE AND REPAIR

I. How the Tissues are renewed

Lead the children to talk of the blood and its work. As it courses through the body it carries fresh supplies of oxygen which it has absorbed in the lungs.

What is the great purpose of this oxygen? It seizes upon the worn-out tissues and burns them up.

What is the advantage of burning them up? The burning converts them into soluble substances; and these are readily absorbed and carried away by the blood.

The waste matters could not be removed in their solid form.

But the blood does more than this. It brings material for building up again those parts of the body which have been worn out by their work. There is not only constant wear and waste, but constant repair going on. This is why a person in good health varies so little in size and weight year after year.

All the materials, whether for making bone, brain, muscle, or any part of the substance of the body, the blood gets from the food we eat.

Tell of the familiar sensation of hunger. When we have not taken food for some time we begin to be conscious of a peculiar

emptiness in the stomach; we feel weary and faint, and unfit for either work or play; we feel a great desire to eat—we are hungry. We go to our meal, and come away with renewed vigour, ready to resume our ordinary occupations.

When a person is in a healthy condition, this desire for food returns several times a day. He is said to have a good appetite.

Indeed, if our appetite falls off, we know that something is wrong; we have to consult the doctor.

If a person were kept without food, his body would shrink and lose weight, and he would gradually become unable to do any work with either mind or body.

All these facts should be elicited from the class.

II. Digestion, what it is

We have learned how the body feeds on the blood; we have next to learn how the blood itself feeds on the food we eat. The food we take supplies new materials to the blood, and the blood carries them to rebuild just those identical tissues that have been destroyed.

The food has actually to be converted into blood. This is the whole work of digestion. It has to change the food we eat into blood fit to feed the body. The bread and butter, meat, pudding, potatoes are solid substances, and quite useless for the purpose in that form.

It is the work of digestion to change the nature of the food we have taken, so as to make it easily soluble.

In this state, and in this state, only, can it ever be absorbed into the blood.

Call upon the children to tell what is meant by "**soluble,**" *and then, to refresh the memory, illustrate as follows:—*

Put some powdered starch in one glass, and some powdered salt or sugar in another; and fill the glasses with water. If the two be now stirred with a spoon, the salt or sugar in the one will entirely disappear, but the starch in the other will still be seen, and will presently sink to the bottom.

The children should be led to explain this.

In the one case, the water holds the salt or sugar in solution, because these substances are soluble in water. We know they are there, because we put them in, and we can detect them if we taste the water; otherwise there is no sign of them there.

In the other glass we have a substance, starch, which does not disappear, because it is insoluble in water.

The salt or the sugar has become for the time inseparable from the water. We could not pour out the water, and leave these substances behind.

Not so with the starch. This settles at the bottom, and we may easily pour off the water alone.

Your bread and butter, and the meat and pudding you had at dinner-time must be so changed that it will disappear and become soluble in the blood, or it can never be any use as food.

We shall next learn how digestion does all this.

Lesson XXXII

DIGESTION

ELICIT from the class, by a few leading questions, that the food we take must be so changed that it will become soluble in the blood, or it can never be of any use to the body.

This dissolving of the food is the work of digestion. We will now find out how this work goes on.

I. IN THE MOUTH

The mouth is provided with a double row of teeth, which act the part of a mill in crushing and breaking up the food. While this crushing work is going on, the food is gradually being saturated with moisture, which oozes out from the lining membrane of the mouth itself.

We call the moisture "**saliva.**" It is a thin watery fluid, and has the power of changing starch into sugar.

Call attention to the peculiar sensation known as "**mouth watering**" *at the sight, smell, or even the recollection of some delicious food.*

We say that "**saliva**" changes "starch" into "sugar." Now let us think for a while about this substance starch.

Refer to the earlier lessons on this substance; and help the children to refresh their memories with regard to it.

Lead them to tell that starch forms an important part of all plants. In some it is very abundant. It is found in the potato, carrot, beet, arrowroot, sago, tapioca, as well as in peas and beans, and especially in the corn grains (wheat, barley, oats, rye, maize, rice, etc.)

The starch which mother uses for laundry purposes is made from wheat or rice flour. It is the same substance which forms so important a part of our food, when made into bread, cakes, puddings, and such like. We could not live without it.

What did last lesson teach us about the two substances "**starch**" and "**sugar**"? Starch is insoluble, and sugar is soluble.

Let one of the children hold a little boiled starch in the mouth for a few minutes, and tell what happens to it. The starch gradually becomes sweeter and sweeter to the taste, and assumes a thin watery condition.

The insoluble starch has been acted upon by the saliva, and changed into soluble sugar.

Tell that this is exactly what takes place with all our starch-food.

It is changed by the saliva, in order that it may at once pass into the blood. It cannot pass into the blood as starch, because starch is insoluble; it is first changed into sugar, and sugar being soluble is absorbed and dissolved in the blood.

This part of our food is being digested as we chew it.

Draw from this a few hints as to the due and proper masti-

cation of our food. Food swallowed in great lumps can be of no use to us, it only gives us pain.

When the work of mastication is completed the food is swallowed and passes into the gullet.

Describe briefly this tube; show it on a diagram.

II. In the Stomach

The lower extremity of the gullet expands into a large bag or pouch, shaped something like a bagpipe. This is the stomach. It lies across the upper front part of the abdomen, immediately below the diaphragm. The diaphragm itself is pierced with a hole to allow the gullet to pass through and join the stomach.

Show on the diagram.

This bag or pouch is very strong and muscular, and is constantly contracting and expanding in such a way as to cause whatever is in it to be rolled and churned about from side to side.

The inside of the bag is crowded with multitudes of tiny little tubes, which are constantly sending out into the bag itself a peculiar fluid—the **gastric juice.** About 3 or 4 quarts of this fluid are sent into the stomach in the twenty-four hours.

So then the masticated food is swallowed, and passes down the gullet into the stomach, where it is mixed with gastric juice, and then rolled and churned about for a long time.

What do you think is the object of all this churning in the stomach? It helps to break up the masticated food still finer.

What can be the object of the "gastric juice"?

Tell that "gastric juice," like "saliva," acts as a solvent for the food. It will not, however, dissolve the starch-food, and it will not dissolve fat. It acts upon lean meat, and upon those parts of the bread, pudding, peas, beans, and such like, which the saliva will not dissolve.

The food which has been thus dissolved by the saliva and the gastric juice is now ready to pass into the blood.

The inner lining of the stomach is a close network of blood-vessels, which branch out into the finest of capillary tubes. In these tubes is the blood, coursing along. On the other side of their thin walls is the great cavity of the stomach filled with food, some of which is digested and dissolved and in the liquid state.

Who can tell me what happens when two liquids are separated by a very thin membrane? The liquids pass through the membrane.

What do we call the process? **Osmosis.**

Osmosis takes place in the blood-vessels of the stomach —at least the dissolved food-matter passes into the blood by osmosis, although the blood does not pass out into the stomach. There is a reason for this, but we cannot go into that now.

III. In the Intestines

The lower end of the stomach leads out, through a somewhat narrow pipe, into the intestines or bowels. They form a long tube, which if stretched out would measure between five and six times the length of the whole person.

They are divided into two distinct portions—the small and large intestines.

1. **The small intestines.**—This is the part of the bowels which joins the stomach. The tube is about five-sixths of the entire length, and is folded and doubled many times upon itself in order that it may be closely packed in the space provided.

Show that it would be impossible to get seven or eight yards of tubing in so small a space, unless it were folded and packed in this way.

2. **The large intestines.**—These begin where the small intestines end, in the groin near the right hip. The tube then passes up the right side, crossing the abdomen

just below the stomach, and then turns downwards again, finally opening externally at the lower end of the trunk.

Show on a good diagram the position of the liver just near the junction of the small intestines with the stomach.

Tell that this great organ has important work to do in connection with digestion.

It produces a greenish-yellow, slimy-looking fluid—**the bile,** and pours it into this part of the small intestines, by a little tube which opens into them. **This bile has the power of dissolving fatty, oily matters.**

The same opening which admits the bile into the intestine also admits another little tube from an organ called the **pancreas.** This tube brings a fluid known as the **pancreatic juice,** which resembles both the saliva and the gastric fluid.

Now let us see what all this has to do with the work of digestion. The whole of the food is not dissolved in the stomach. All that remains in an undigested state passes out into the small intestine. There it receives bile from the liver to dissolve the "fats," and **pancreatic** juice from the **pancreas** to complete the work of digesting or dissolving. The walls of the intestines are strong and muscular, and as they contract they force the stream of food onward—the fluids digesting it as it goes.

Lesson XXXIII

ABSORPTION

I. Introduction

Commence by making the class describe again the passage of fluids through a membrane by osmosis.

Tell that all fluids have not this osmotic force to the same extent. Some pass more easily through a membrane than others,

and some will not penetrate at all. For example, osmosis will not take place with starch, but sugar solution passes readily through a membrane.

Put some white of egg or some oil into a bladder, and immerse the bladder in a vessel of water. No exchange takes place, because these substances cannot pass through the membrane by osmosis.

Explain that what is left of the bread and pudding, peas and beans, after the starch has been removed, is a substance very like white of egg. Lean meat too is made of this same substance.

It cannot pass from the stomach into the blood by osmosis, till after it has been **dissolved by the gastric juice.**

Fat is like the oil in the bladder, and has no osmotic force. **It will not pass into the blood until it has been dissolved by the bile from the liver.**

A gall-bladder should be obtained, and its contents examined by the class.

Show that it has a peculiar soapy feel, and is strongly alkaline in its properties.

Refer to the early lesson on soap and soap-making to describe this property.

Take a bottle that has contained oil and is still very greasy, fill it with water and shake it for a time.

Show that when you pour off the water the oil still remains round the sides of the bottle, because water will not dissolve oil.

Now fill the bottle again with water, add a piece of common soda, and shake up as before. The whole becomes white and milky, because the oil has been dissolved with the help of the alkaline soda.

The liquid may now be poured off, leaving the bottle clean.

Repeat in a similar bottle with some of the contents of the gall-bladder (bile).

Show that this **bile has the properties of soda.** *It will dissolve oil and fatty matters.*

II. Direct Absorption

Tell again that the inner lining of the stomach and intestines is thickly set with a close network of exceedingly small blood-vessels. The walls of these tubes are extremely thin; indeed the tubes themselves are the merest hairs or threads.

While the churning process is going on in the stomach, the pulpy food is being constantly washed up against its sides, and osmosis takes place with those parts of the mixture which are capable of passing through a membrane.

Lead the children to tell that these will be the sugary parts of the food, the starches which have been converted into sugar by the action of the saliva, and the substances which the gastric juice has dissolved.

Some of these remain undissolved, and so does all fatty, oily matter. They pass out of the stomach into the intestines. Here **the bile from the liver** takes charge of the fats, and **dissolves** them. But what is the name of the other fluid which is poured in side by side with the bile? **The pancreatic juice.**

Tell that this **pancreatic juice** *carries on the work of converting any remaining starch into sugar, and of dissolving all other matters that were not dissolved in the stomach. As they are rendered osmotic, they are sucked up at once into the blood all along the intestinal canal.*

III. Absorption by Villi

The inner surface of the small intestines is not smooth like the outside of the tube, but is covered with a multitude of tiny thread-like projections, set close side by side, like the pile of velvet.

Show, if possible, a piece of tripe, or a portion of the small intestine of a pig.

It is estimated that there are no less than four millions of these little hanging threads in the walls of the small intestines. They are called **villi**

They may be compared to a multitude of tiny tongues hanging down into the tube. They are being constantly bathed by the stream of digested food as it passes along the intestinal canal.

These little tongues suck up from the stream the dissolved fats which it contains.

Structure of a villus.—Each little villus, small as it is, is really a very complicated structure. It has running through its centre a tiny tube, which forms at its extremity an extremely fine network of still smaller tubes.

Illustrate with a simple drawing on the black-board.

This is not for the purpose of carrying blood.

It is called a **lacteal.** The name "lacteal" comes from the Latin word *lac*, meaning "**milk.**" It signifies "**milky-looking.**" The name is given to these vessels because of their white, milky appearance an hour or so after a meal.

Tell that this white, milky appearance is actually due to the minute particles of fat which they have absorbed from the intestines after the bile has dissolved and broken them up.

The work of these tiny tubes, the lacteals, is to absorb the digested fatty parts of the food. All the fat which enters the blood is carried to it through the lacteals. The lacteals gradually unite into larger vessels in the walls of the intestine, and these at last form a great trunk or pouch called the **thoracic duct.**

Tell the meaning of the term "duct," and why it is called the thoracic duct.

It is about 18 inches long, and about the size of an ordinary goose-quill. It lies along the front of the spinal column, and reaches upwards to the root of the neck.

The thoracic duct forms a sort of **reservoir or receptacle for the dissolved fats** which are sucked up by the lacteals, and poured into it.

At its upper extremity it opens into a great blood-vessel known as **the left sub-clavian vein.** Thus the fatty matters taken up by the lacteals at last reach the blood, and the work of digestion is completed.

GEOGRAPHICAL DISTRIBUTION OF PLANTS MOST USEFUL TO MAN. TRADE AND COMMERCE ARISING THEREFROM.

PLANTS USEFUL FOR FOOD

Lesson XXXIV

BREAD-FOOD—THE CEREALS

In no part of our daily wants do we show our dependence on the vegetable kingdom so much as in our food. All our food is, directly or indirectly, of vegetable origin; for although we eat the flesh of certain animals, the animals themselves derived their support all their lives from plants of one kind or another.

What is the most important of all our vegetable food? Bread.

Explain that man in every part of the globe makes bread of some kind his staple food; that this bread is not always made of the same sort of material; but that in every case it is a vegetable substance.

The cereals (corn grains) form the bread-making materials for the greater part of civilised mankind. They provide the staple food of more than four-fifths of the population of the globe.

I. Composition of the Corn Grains

Show some samples of the various corn grains. Lead the class to tell, from their former lessons, the composition of these grains. They all contain **starch** *and* **gluten.**

Taking wheaten flour as an illustration, let them explain how these two principal constituents may be separated out.

Lead them to tell the value of the gluten as **a flesh-former.** *It is the gluten of the grain which supplies all the nutritive food.*

The various corn grains owe their importance as food-stuffs chiefly to the amount of gluten which they contain.

In which part of the corn grains is the gluten found? In the outer part immediately under the skin or husk.

Show a sample of the finest white wheaten flour, and some whole meal. Explain that the whole meal is obtained by simply grinding the grain, without sifting out the bran; but that the "fine white flour" has been sifted several times to remove all the bran.

The bran of English wheat contains 16 lbs. of gluten out of every 100 lbs.; the fine sifted white flour not more than 10 lbs.; the whole meal usually contains rather more than 12 lbs. of gluten in the 100.

Bread, therefore, made from whole meal is more nutritious than that made from fine sifted white flour.

II. A Comparison of the Corn Grains

Oatmeal is very rich in gluten: it contains about 16 per cent of this substance—about the same proportion as in the bran of English wheat.

Barley and rye contain about the same proportion of gluten as wheaten flour, but the meal is coarser in flavour and colour, and the bread made from them, instead of being light and spongy, is heavy and close.

Rice is remarkable among the corn grains as containing the smallest proportion of gluten. The amount is not more than 7 or 8 per cent—about half the amount found in oatmeal.

Maize contains only about 9 per cent of gluten, but it is richer in fatty or oily matter than any of the other grains. This makes it more easy of digestion, and it is well adapted for fattening animals.

Let us see now how Nature suits her foods to the requirements of the various populations of the world.

Starting with rice, explain that this grain forms the food of **about one-third of the entire human race.** *The majority of these people inhabit the tropical and sub-tropical regions of the world. From the nature of the climate these people are unable to undergo the physical and mental labours which form the everyday life of man in the more temperate climates. Hence the bodily wear and tear are less, and the need of nutrition also less. Added to this, rice is one of the most easily digested foods. The nature of the hot climate, moreover,* **has a relaxing effect,** *and rice, containing as it does very little fat, is less relaxing than any other of the corn grains. In fact it is rather binding than relaxing in its effect. It is just the food suited to such people and such climates.*

Show too that this special food which Nature supplies for these regions is cultivated easily there, where the other corn grains could not be grown.

Notwithstanding these things, Europeans in those countries have always been astonished at the enormous quantities of rice the natives are obliged to devour at a meal, because of the small amount of the necessary gluten which the grain contains.

In cold, bracing climates, such as that of Scotland, **oatmeal forms the staple article of diet.** But the same food would not be found suitable in warmer and more relaxing climates, as **oatmeal itself has a decidedly relaxing effect.**

Show again that the food which Nature in this instance provides is a hardy plant, able to withstand the rigour of the climate in which wheat cannot be grown.

III. Trade in Bread-Stuffs

Lead the class to see that, owing to the density of our British population, it would be quite impossible for the country to provide sufficient home-grown corn.

We import largely from other countries. Wheat cannot be grown in England, at a fair profit to the grower, under 40 shillings a quarter; but it can be imported from America and other parts and delivered in Liverpool at 23 shillings a quarter.[1]

In 1882 we imported no less than 64,240,749 cwt. of wheat. Of this quantity 24½ million cwt. came from the United States; 11 million cwt. from India; 3 million cwt. from Canada; and the rest mostly from Russia.

Maize is imported to the extent of about 2 million tons every year. It is mostly used as **corn-flour, oswego,** and **maizena**—preparations employed for blanc-manges, puddings, biscuits, etc. It is a most useful grain, but it will not ripen in our climate.

Since 1885 maize has been much used in the preparation of **glucose,** a kind of sugar used in brewing and confectionery.

We import annually from 6 to 10 million cwt. of barley, mostly from the northern countries of Europe. It is chiefly used for brewing, and for feeding cattle and poultry.

About 3 million acres in Great Britain are devoted to the cultivation of oats; and in addition we import largely.

Rye forms the chief food of the masses in Russia. In this country it is grown and cut green for feeding horses.

Buckwheat is grown largely in America, and makes very nutritious flour. In the backwoods of America it is made into delicious cakes, which are eaten hot with maple-honey. We import buckwheat for feeding poultry.

Dari or **Dhoora** is a small kind of grain largely cultivated by the people of India, Egypt, and Central Africa for their own use. It is commonly known as **millet,** and yields a beautiful white meal, containing 8 to 9 per cent of gluten. We import it as we do buckwheat for feeding poultry.

[1] Competition, and the abundant harvests everywhere, have this year (1894) compelled the British farmer to quote good new Essex and Suffolk wheat at 20 shillings a quarter; and other varieties as low as 17 shillings. If he had no rent to pay for his land he could not afford to sell at these prices. Hence the cultivation of wheat in this country cannot long continue.

Lesson XXXV

OTHER BREAD-STUFFS

I. Pulse

The bean, pea, lentil, lupin, and vetch are included under the common name of **pulse.** They form a most useful class of bread-stuffs, and enter largely into the food of both man and animals.

Show samples of each of those named, and let the class explain that they are all the seeds of the plants on which they grow.

Lead them to tell from their knowledge of green peas, broad beans, and kidney beans that these pulse seeds grow in pods; and that we use them in the green unripe state as fresh vegetables, as well as in their ripened state.

1. **Properties of pulse.**—The usefulness of pulse is due to the fact that they contain a large amount of **glutinous** (tissue-forming) matter, and a very small percentage of fatty or oily matter. A hundred pounds weight of pulse would average about 24 lbs. of gluten, and only about 2 lbs. of fat or oil.

The gluten of pulse is known as **legumin.** It resembles the gluten of oats rather than that of wheat.

Call upon the class to compare the light, spongy, wheaten loaf of England with the oatcake of Scotland.

Tell that the Scotch people do not make their oatmeal into close cakes in preference to loaves of bread; they do it simply because oatmeal will not make up into light, spongy loaves.

Pulse meal, although it is highly nutritious, is like oatmeal in this respect; **it will not admit of being made into light, spongy bread.** In those countries where it is most eaten it is prepared in the form of cakes.

Eaten alone, this food has a constipating or costive effect, probably owing to the small proportion of fat it contains. Oatmeal, which contains as much as 10 per cent of fatty

matter, has rather a relaxing effect, as we learnt in the last lesson.

Explain that a mixture of beans and oats is found to make the best food for horses which are engaged in hard, laborious work. Both foods contain a large proportion of gluten; and the abundance of fat in the oats makes up for the deficiency of fat in the beans. This mixture of food gives more strength and endurance than any other.

There is a small kind of pulse grown in the East, and known as "**chick-pea**" or "**gram.**" Travellers about to cross the deserts carry with them a supply of these peas, roasted ready for use. Heavy, bulky food would be an encumbrance; these peas are light and take up little room, while they are said to be more life-sustaining in their properties than any other food.

2. **Varieties of pulse.**—*Show some French or kidney beans. If the season permit, show the green as well as the ripened pod.*

These beans are natives of India, but they are now grown in most temperate climates. The useful **haricot-bean** is simply the ripe seed of the **French bean.**

Show some specimens, and explain their uses.

Show specimens of **broad or Windsor beans,** *if possible, both in the green and also in the ripened pod.*

We not only grow this kind of pulse largely for use as a green vegetable, but we import great quantities in the ripe state for feeding horses. They are commonly known as **horse-beans.**

Lentils yield a highly nutritious meal. From it is prepared the well-known food for infants and invalids—**revalenta.**

In Lombardy (North Italy) **lupins** are grown very extensively, and the meal which they yield forms the staple food of the people.

Show some **ground-nuts.**

They have another name—**pea-nuts,** but they are best known to children under the name of **monkey-nuts.** These properly belong to the pulse family, and in the

tropical regions where they are grown they are used as food both by man and animals.

They contain about 50 per cent of oil. We import ground-nuts into this country for the sake of the oil, which is worth from 20 to 30 shillings a ton, and is employed in **soap-making.** This oil is used in India as a substitute for olive-oil.

The residue left after pressing out the oil forms a valuable oil-cake, worth from £8 to £15 a ton.

II. Sago

The class should be led to tell from the earlier lessons that the sago of commerce is obtained from the **pith** *of the* **sago-palm.**

This tree is a native of New Guinea and some parts of the coast of Africa. A fully-grown tree yields about 700 lbs. of sago-meal; and it is said a healthy man can live on 2½ lbs. of this meal a day.

The tree, when mature, is cut down, and the pith, after being extracted, is washed in water on a sieve. The meal, which is mostly starch, settles at the bottom of the water, and is collected by draining off the water, and drying in the sun.

The natives bake the meal into **a kind of bread** or **hard cake.** We import sago to the extent of about £200,000 worth annually.

In 1886 Singapore alone sent us 364,188 cwt. of sago.

III. The Bread-fruit

Show, if possible, a picture of this wonderful tree. Explain that to the natives of the great Pacific and Indian archipelagoes the fruit of this tree is the staple article of food. It is to them what our wheaten loaf is to us. **It is their bread.**

The fruit grows very abundantly, each tree bearing and ripening crop after crop in succession for about eight or nine months of the year. So abundant are the crops, that three trees are sufficient to support a full-grown man for

eight months of the year. It contains a porous and mealy pith enclosed in a tough outer rind. It is usually plucked before it is quite ripe, and baked on hot stones. It is said to **taste,** when cooked, **very much like wheaten bread.**

IV. The Banana or Plantain

Show a picture of this tree.

It is a native of Central America and other tropical countries; and to the people of these regions the fruit of the banana becomes the principal food.

A sample of the fruit might be easily obtained. Procure one, if possible, and have it examined.

Within the outer rind is a more or less mealy substance, which when dried in the oven resembles bread both in taste and composition. **It is the bread of the people in those parts of the world.**

In composition it is less nutritious than some of the other food-stuffs we have named, as it contains only about 2 per cent of gluten mixed with about 20 per cent of starchy matter.

The average daily allowance of food for a labourer in those regions is about 2 lbs. of the dry banana meal, with the addition of ¼ lb. of meat or fish. This is said to afford ample sustenance.

A single tree bears from 40 to 70, and sometimes 80 lbs. weight of fruit.

No plant in the world is so prolific in its products as this tree.

It has been calculated that 1000 square feet of land will produce, on the average, 462 lbs. of potatoes or 38 lbs. of wheat; but that the same space will produce as much as 4000 lbs. weight of bananas, and in shorter time.

V. The Date

This fruit, which is the produce of the date-palm, has been justly called the "**bread of the desert.**"

Show a picture of the tree, and some specimens of the fruit, if possible.

Its home is the northern part of Africa. Wherever a spring of water exists in those burning sandy deserts, the date-palm is sure to be found. When every other crop fails, this tree will flourish in spite of the drought.

The people of the oases dry and pound the fruit into a kind of cake, and **it becomes the bread of nineteen-twentieths of the population** for the greater part of the year.

Lesson XXXVI

OTHER USEFUL VEGETABLES

I. Introduction

Lead the class to think over the last two lessons on bread-stuffs. Let them prove, as a result of those lessons, that man in all parts of the world makes bread in some form or other his staple food; although bread is not always made of the same materials.

What are the essential constituents in all these bread-stuffs? Gluten and starch.

Why are these essential?

Elicit that the cereals are the most important class of bread-producing plants—that they feed quite four-fifths of the human race.

Let the children mention other plants which supply bread-foods, and tell in each case the part of the plant which yields the food-supply.

We are now going to deal with some other plants which enter largely into our daily supply of food. In some we depend upon the **root**; in others the **stem** or its **tubers** yield the supply; in others again we use the **leaves** of the plants.

II. Roots and Tubers

Call upon the class to mention some plants whose roots supply us with food. The potato will probably be named through

thoughtlessness. Tell that this is wrong. Make the class explain why it is wrong to call the potato a root. The potato is a tuber, that is, a swollen part of the underground stem of the plant.

The carrot, turnip, and parsnips are true roots—the fleshy tap-roots of the respective plants.

It will be easy to show that these underground parts of the plant (roots and tubers) must of necessity contain a large amount of water. They are constantly absorbing water from the soil.

Every 100 lbs. weight—

of turnips contains 92 lbs. of water, and 8 lbs. of dry solid matter;

of carrots contains 88 lbs. of water, and 12 lbs. of dry solid matter;

of potatoes contains 75 lbs. of water, and 25 lbs. of dry solid matter.

If these roots and tubers be dried until all the water is driven out of them, the dry solid matter will be found to consist mainly of the same substances (gluten and starch) with which we have become familiar in the bread-stuffs.

It is because they contain these substances that they are valuable as nutritious foods.

The dried solid substance of the parsnip, for instance, **yields a meal** which consists of **gluten** in addition to **starch** and **sugar** combined. Hence it forms a very nutritious food.

The **turnip** is said to be quite equal in its composition to the meal of Indian corn, except that it is deficient in fatty matter. Therefore to make turnips a really nutritious food they should be eaten with some fatty or oily food.

Remind the class that, on the same principle, the farmer makes turnips combined with oil-cake the main food of his cattle during the winter months, when they are for the most part housed, and unable to seek their own food in the meadows.

The **mangold-wurzel**—one of the turnip family—is **a valuable root** to the farmer **for cattle-feeding.**

The potato is by far the most important of the tubers

used as food. Indeed, **next to the cereals, the potato is the most valuable of all vegetable foods.**

It feeds domestic animals as well as man, and is more extensively and universally grown than any other cultivated plant. It is very largely cultivated in mild climates, and to some extent in warm and even in cold regions.

The 25 per cent of dry solid matter which it contains consists largely of starch, with less gluten than is found in rice, banana, or bread-fruit; yet in conjunction with other food it forms a valuable article of diet.

To the Irish peasant it is as much the staple food as rice is to the Hindoo and Chinaman, or the banana to the negro.

The sweet potato of Central America, and the yam of the East and West Indies and the South Sea Islands, are varieties of the potato which form important articles of food in the regions where they are grown.

The onion is a most valuable and nutritious article of food; the dried solid substance of the bulb is found to contain from 25 to 30 per cent of flesh-forming gluten. In its sustaining power it is said to equal the **gram** of the Eastern desert-lands.

It is largely cultivated in this country, and is also imported from Spain and Portugal to the extent of seven or eight hundred tons a year.

The Spanish peasant works contentedly from day to day on a diet of bread and onions—the onions contributing very largely to the amount of nourishment provided by his simple meal.

The onion is the swollen bulbous stem of the plant.

III. Leaves

The leaves of plants provide a considerable proportion of our daily food, both directly and indirectly.

Our sheep and oxen and other animals, whose flesh supplies us with food, live for the most part on grass.

The cabbage family of plants, including the cauliflower,

broccoli, etc., are extensively grown in all European countries.

They contain a large proportion of water—as much as 90 per cent; but their dry solid matter is **rich in flesh-forming gluten,** and this makes them a highly nutritious article of diet.

A common dish in Ireland and in the South of France is made of potatoes and cabbage beaten up together. The **potato supplies abundance of starch,** but little gluten; the cabbage is **rich in gluten**; the two combined approach the composition of wheaten bread. Add to the mixture a little fat pork, and the whole gives all the constituents of Scotch oatmeal.

One important constituent of every variety of vegetable food we have hitherto ignored. If we burned any one of the food substances we have examined, we should leave a residue—the mineral ash. This ash represents the earthy or mineral matters absorbed from the soil by the plant during its life. These mineral matters are of the highest importance to the growth and well-being of the body—particularly in the work of bone-making.

Lesson XXXVII

FRUITS AND NUTS

I. Fruits

Elicit from the class that in some parts of the world the populations depend upon the fruits natural to the soil for their chief food-supply.

Thus the **Arab** of North Africa and Arabia lives almost entirely on the **date**; the **negro** of the tropics on the **banana**; the **South Sea Islander** on the **bread-fruit.**

We in temperate climates regard fruit rather as a luxury than a necessary of life.

Let the class name the common English fruits—such as apples,

pears, plums, cherries, apricots, peaches, strawberries, raspberries, gooseberries, currants, etc.

In addition to these (our home-grown supply, and most of which are cultivated in all parts of the country), we every year import immense quantities of fruit.

Steam navigation has had the effect of bringing distant lands into such close touch with our own, that we are able to enjoy, all the year round, at moderate cost, the fruits of foreign countries in addition to those of our own island.

Most of our foreign fruit-supply comes from Spain, Malta, the Madeiras, the Canary Isles, the United States, and the West Indies.

Tasmania has of late years sent us immense cargoes of excellent apples.

In 1886, we imported fruit to the amount of £3,652,225 sterling. This, in addition to our home-grown supply, shows the importance of fruit as an article of food.

In the same year (1886) the amount of apples alone imported was no less than 3,261,460 bushels; and more than half this quantity came from the United States.

Our annual imports of oranges and lemons amount to nearly 5 million bushels. The greater part of these come from Spain. The St. Michael's (the richest and most delicate-flavoured variety of the fruit) takes its name from one of the Azores or Western Islands, where it was first exclusively grown.

The Seville or bitter orange (from the south of Spain) is used in the manufacture of marmalade.

The Malta orange is a small variety known as the Tangerene.

The lemon, sweet lime, shaddock, and citron come mostly from Madeira.

The pine-apple is largely imported from the Azores and Bahamas.

The banana of Central America and the West Indies, and the pomegranate of Southern Asia are both to be seen in our fruiterers' shops; and we almost import hundreds of tons of fresh grapes, most of which come from Spain.

Lead the class to think of the grocers' shops, and they will at once tell of a different class of fruit—raisins, currants, figs.

These we call dried fruits, to distinguish them from those which we have mentioned, and which are known as **raw** or **green fruits.**

Our annual import of dried fruits amounts to no less than 20,000 tons.

Raisins come from Valencia and Malaga in Spain; sultanas (a seedless variety) from Smyrna; and currants from Smyrna and the Ionian Islands.

Explain the name "currant." It has nothing to do with our English red, white, and black currants. Raisins and currants are both dried grapes. The currant takes its name from Corinth. It is the Corinth grape.

Figs come mostly from Smyrna. We import several hundreds of tons annually.

II. NUTS

The most wonderful nut in the world is the **coker-nut.** This is the fruit of one of the most useful of the tropical palms—**the coker-nut palm.**

This word is sometimes spelt "**cocoa-nut,**" *sometimes* "**coker-nut.**" *We shall use the latter spelling here, to distinguish the tree and its products from the true* "**cocoa-tree,**" *which is not a palm at all. Either spelling is correct.*

This tree is very widely distributed throughout the tropics. It is met with in the East and West Indies, in Central America, in India and Ceylon, and in all the islands of the Pacific and Indian archipelagoes.

The trees are usually found fringing the low shores.

In Ceylon there are extensive plantations of these palms, said to contain no fewer than twenty millions of trees.

The coker-nut palm is a stately tree rising often to the height of 100 feet; its summit is crowned with long graceful feathery leaves from 12 to 15 feet in length. It bears immense bunches of flowers, and when these die off

they give place to the fruit—the coker-nut of commerce. The tree usually bears about 60 nuts each year.

The nuts, as we see them in the shops, have been stripped of their outer covering—which is a thick fibrous case or husk. This supplies the material for coker-nut matting, brushes, etc.

To the natives of the lands where it grows this tree is invaluable. Its uses are said to equal in number the days of the year. They build their houses and make every utensil and household article they require from the wood of the trunk. They thatch the houses with the leaves; and the fibrous husk provides them with matting. The nut itself forms an important part of their food; the milk supplies them with drink; and they make "palm wine," and "arrack" a spirituous liquor, from the fermented juice or sap of the flowers. From the kernel of the nut is obtained the valuable cocoa-nut oil, which is largely used in candle-making.

We import annually about £300,000 worth of cocoa-nut oil from India and Ceylon alone. Most of it is used in the manufacture of marine soap—a soap that will form a lather with sea-water.

The timber of the trunk is also a valuable article of commerce. It is known as **porcupine wood.**

Among the other common nuts are the **filbert, walnut, almond, chestnut,** and **Brazil.**

Hazel-nuts and filberts are natives of our own country; but we import large quantities from Spain, under the name of **Barcelona nuts.**

The walnut is also grown in this country; but we import many thousand bushels every year from Germany and the South of France.

The almond belongs to the countries bordering on the Mediterranean. There are several varieties—the sweet almond, the bitter almond, the Valencia, and the Jordan almond. This last has nothing to do with the river Jordan. The name is a corruption of *jardin*, the French word for "garden."

The chestnut is extensively grown in Spain and Italy. The people of Lombardy **mix chestnuts with their lupin meal to make their bread.**

We import chestnuts largely from Holland and Belgium.

The Brazil nut is the fruit of a large tree which grows mostly in the region near the Orinoco. The fruit is a smooth round case, half as big as a man's head, and in it the three-sided nuts are packed closely together, as many as twenty or thirty in one case.

It is extremely dangerous to pass under the trees when the fruit is growing ripe; for the nut-cases, owing to their great weight, frequently fall as they ripen.

The natives have a novel way of obtaining the nuts without the trouble of climbing the tall tree. The forests are swarming with monkeys. They chase the monkeys into the trees, and then pelt them with stones. The monkeys pluck the nut-cases from the tree and hurl them down at their assailants.

Lesson XXXVIII

SPICES

Show specimens of the various spices—cloves, nutmeg, mace, cinnamon, ginger, pepper, and allspice. Let the class say what they are, and tell their uses as far as they can. The specimens may then be dealt with one by one.

I. Cloves

Hand some cloves round the class, and commence by calling attention to their powerful aromatic odour.

Set the children to chew some of their cloves, and call upon them to describe the strong pungent flavour. It is a good thing to chew a clove or two before taking any bad-tasting medicine. The strong stinging flavour of the clove destroys the disagreeable taste of the medicine.

Explain that, like all the other spices, they owe their importance to these properties. They are valuable as flavourers.

The cloves which we have before us are **the dried flower-buds of a kind of myrtle-tree.** The tree itself is a very beautiful evergreen, which grows four or five times as high as a man.

When the flower-buds first appear they are of a pale yellow colour, but they gradually pass to green, and finally to a bright red. As soon as they begin to turn red, and before they open into actual flower, they are plucked, and dried in the sun. When dried, they assume the dark brown colour with which we are familiar.

Call attention to the little ball or knob at the end of the clove. This is the actual flower folded up.

The name "clove" is given from the Latin *clavus*, a nail, because the clove is said to resemble a little nail.

Cloves are used in cookery as a seasoning. When pressed, they yield "**oil of cloves**," which is largely used in perfumery and medicine.

The clove is a native of the Moluccas or Spice Islands, but it is now grown in Sumatra, Mauritius, Zanzibar, Brazil, and the West Indies.

II. Nutmegs

Show some specimens, and, as before, have them examined by the class to discover their rich aromatic odour and flavour. This would be best done by grating one of the nutmegs on a grater.

The nutmeg of commerce is **the seed of an evergreen tree** which is a native of the Moluccas, but is now grown in most of the East India Islands, and in the West Indies and South America.

The fruit when ripe is a rich golden yellow, and something like a peach. Indeed it is **a kind of stone-fruit.** The outer fleshy part encloses the stone. This is a hard brown shell, and contains a round nut or kernel—the actual nutmeg.

As the fruit ripens, the outer fleshy covering splits, and then may be seen the dark brown, almost black shell of the kernel, enclosed within a leafy-looking network of a brilliant red colour.

This is the time for gathering. The fleshy outside part is not unlike candied fruit, and is preserved and eaten as a sweetmeat.

The bright red network-covering is stripped from the shell and dried. As it dries it assumes a yellow colour, and becomes **the mace** of commerce.

The nuts themselves are carefully dried in the sun until the kernels begin to shrink and can be heard to rattle in the shell when they are shaken. The shells are then broken with wooden mallets, and the kernels—**the actual nutmegs**—sorted for use.

The smallest of the kernels are not sent into the market. They are pressed, and made to yield a valuable oil, known as "**oil of mace.**"

III. Cinnamon

Show some rolls of cinnamon. We have now to examine a spice which is neither the flower-bud nor the fruit of the plant. What is it?

Cinnamon is **the inner bark of another tropical evergreen.** The best cinnamon is grown in Ceylon, but it is now to some extent cultivated in China and South America.

The tree is usually grown from seed, and the branches are cut when they are from two to three years old. They are then about the size of an ordinary cane. The bark is peeled off with a knife, and laid in the sun to dry. As it dries, it turns brown, and curls up into little rolls as we now see it.

Cinnamon is a very valuable spice. It is used largely in cookery, confectionery, and perfumery.

IV. Ginger

Hand some ginger round the class. Let the children, as before, examine it for taste and smell.

Lead them to tell that this again is neither the flower-bud nor the fruit of the plant, neither is it the bark. What is it?

Ginger is **the underground stem of a plant something like a common reed,** which is cultivated in most tropical countries. It was originally a native of Southern Asia and the adjoining islands, but is now largely grown in the West Indies as well.

The ginger of Jamaica now fetches the best market prices.

A delicious sweetmeat is made by preserving the young shoots in sugar-syrup. It is known as **candied** or **preserved ginger**.

V. Pepper

Show some peppercorns. Explain that they are **the dried berries of a climbing shrub** *which is a native of the East Indies, and is now cultivated in most tropical countries.*

Pepper, although a condiment rather than a spice, is usually classed with the other spices.

Show some ground pepper.

Black pepper and white pepper come from the same berry. If the dried berry is ground as it is, we get black pepper. White pepper is obtained by soaking the berries in water and rubbing off the black outer covering.

VI. Allspice

Show some of the berries, and compare them with the pepper-corns.

Allspice is **the berry of an evergreen shrub—the pimento,** and is sometimes called Jamaica pepper. It is

grown in that island and the other West India Islands, and in South America. The name allspice is given to the berry because it is said to have the flavour of cloves, nutmeg, and cinnamon combined.

Lesson XXXIX

SUGAR

Call upon the class to mention some of the various ways in which we use sugar.

It has become almost a necessary of life to us. It is estimated that we consume, on the average, no less than **70 lbs. of sugar** per head of the population in the United Kingdom each year. We are by far the largest consumers of sugar in the world. Upwards of **one million tons** of sugar are annually imported into this country.

Lead the children to think of the millions of men in various parts of the world who are employed in cultivating the plants, extracting and preparing the sugar, and conveying it to this and other countries; to say nothing of the traders and others through whose hands it must pass before it reaches the actual consumer. **Thousands of ships** *are employed in carrying this one article of commerce.*

Sugar is one of the most important productions of the vegetable kingdom. It is obtained from many plants, each having its own special characteristics.

It is usual to arrange the various sugars under three heads—**grape-sugar, cane-sugar,** and **manna** or **leaf-sugar.**

I. Grape-Sugar

Show some raisins. What are these? They are ripe grapes which have been dried in the air. Open some of the raisins, and call attention to the white crystalline substance inside. Have it tested for taste, and let the class tell that it is sweet—as sweet as sugar.

Explain that this white substance **is really sugar.** *We call it* **grape-sugar.** *It is the main source of the sweetness in the raisin, as well as in the currant, which is also a kind of grape.*

Not only the grape but fruits in general owe their sweetness to this same kind of sugar—**grape-sugar.** The apple, pear, plum, gooseberry, cherry, etc., have at first a sharp, sour taste, and gradually pass from sour to sweet as they ripen. This is because **grape-sugar** is being formed in them. Even when fully ripe most of them are a little sour; and it is the mixture of sour and sweet which gives fruit its pleasant flavour.

We could if we chose extract the sugar from the fruits for use; but it is much more economical and certainly much more pleasing to the taste to use the sugar as it exists in the fruits themselves.

This grape-sugar of the fruits yields wine when fermented.

Lead the class next to think about the **starches.** *Let them name as many of the starch-foods as they can.*

What do we notice if we mix a little starch in water and put some of it into the mouth? In a short time the starch becomes sweet.

Why is this? The starch has been changed into sugar by the saliva in the mouth.

What must happen to all the starch-foods we eat before they can be of use in the body? They must be changed into sugar. The saliva is an acid fluid, and changes starch into sugar.

The kind of sugar formed is the same grape-sugar which we have met with in the raisin, the currant, and other fruit.

Starch is insoluble in water, and even if we boil it in water, it remains unchanged. It is starch still.

Mix some starch in water, add a little sulphuric acid, and boil it in the evaporating dish over the spirit-lamp. As soon as it is cool it may be tasted, when it will be found to have acquired a sweet taste. The acid will have converted the **starch** *into* **sugar—grape-sugar.**

We could, by adding lime to the solution, separate the

acid, and then if the liquor were boiled down, **we should get actual sugar.**

Potato, wheat, barley, rice, or sago starch can be readily made to yield sugar in this way.

The sugar obtained from starch is known as "**maltose.**" It is made into beer by the process of brewing.

II. Cane-Sugar

The sugars we have described are not the sugars of commerce, prepared specially and used for ordinary sweetening purposes.

All the varieties of sugar known in commerce are grouped under one heading as **cane-sugars.** These do not all come from the **sugar-cane,** although that plant is still one of the chief sources of our sugar-supply.

Besides that obtained from the sugar-cane, we have **beet-sugar, palm or date sugar, maple-sugar,** and **maize-sugar.** The common name **cane-sugar** is given to all of them because in their properties they all resemble the sugar of the sugar-cane.

The preparation and sale of beetroot-sugar is largely increasing every year. We now consume more of this than of any other kind.

In 1884-85 we imported **2,546,000 tons of beet-sugar,** as compared with **2,260,100 tons of the sugar-cane produce.** This was not all consumed at home; much of it was sent out of the country again as a manufactured article.

1. Sugar of the sugar-cane.—*Show a picture of the sugar-cane. Explain that the plant was originally a native of the Old World, and that it was introduced into the New World by the Spaniards in* 1520. *It is now very extensively cultivated in America and the West Indies, as well as in India and the East Indies.*

It is estimated that the total yearly production from the sugar-cane all over the globe is upwards of **5000 millions**

of pounds, and by far the greater part of this comes from British dominions, chiefly the East and West Indies.

Describe briefly the sugar-cane itself, and its cultivation; the sugar-harvest; the method of extracting the juice; the boiling process; raw sugar.

In countries such as our own, sugar is regarded only as a luxury; but in the tropical regions where the sugar-cane is cultivated it is a staple article of food. Men, women, and children suck and chew the ripe stalk, and the negroes practically live on it, and get fat, in the sugar harvest-time.

The raw juice contains not only the sugar, but a considerable amount of **gluten** in addition. Hence it is in all respects **a true food,** capable alone of supporting life and animal vigour.

During the processes of preparation, the juice loses this gluten, so that the sugar of commerce is no longer a true food.

2. **Beetroot-sugar.**—*Show an ordinary beet. Tell what it is, and how it grows. One already boiled for the table would be best for the purpose. It might be cut in slices and given to the children to taste. It has a very sweet taste.*

Explain that there is a variety of the beet, known as **the sugar-beet,** *much sweeter than these. It contains as much as one-eighth part of its weight of sugar.*

The sweet juice is easily extracted from the beetroot, and when boiled and refined it has all the properties of cane-sugar.

Beetroot is extensively grown for its sugar in France, Belgium, Russia, Germany, and other countries of Europe. In fact, beetroot-sugar is commonly known as European sugar. In each of these countries the manufacture of beet-sugar forms a most important industry.

3. **Palm or date sugar.**—The date-palm, and indeed most of the palms, yield a sweet juice, which when boiled down gives a brownish raw sugar, commonly known as **"jaggery."** The juice is most abundant in the topmost shoots of the tree, and is obtained by piercing the shoots, or otherwise wounding them, so as to cause the juice to flow.

Jaggery, or **East India date-sugar,** is in all respects the same as the other cane-sugars. It is produced by the people of India and other tropical regions where the palms grow, mostly for their own consumption. The total annual amount of palm-sugar produced is estimated at **150,000 tons.**

4. **Maple, or North American sugar.**—*Show a picture of the sugar maple-tree.*

It is a large, handsome tree, often attaining the height of 60 or 80 feet.

Explain that the tree is a native of Canada and the parts of the United States which lie near the great lakes; here extensive natural forests of maples cover vast tracts of country.

The sap of the tree is very sweet. It contains the same kind of sugar as the sugar-cane. The sap begins to flow in February, and when March comes, parties of sugar-makers start for the forest. They make incisions into the trunks of the trees, and place small buckets below to catch the sap as it flows. They usually fit into the holes little pipes made of elder-shoots, to assist the flow of the sap into the buckets.

The sap is collected twice a day and boiled on the spot in earthenware pots. Two or three men can usually make, in the season (March and April), as much as **4000 or 5000 lbs. of sugar.**

The total annual production of maple-sugar is estimated at about **45,000,000 lbs.**

5. **Maize, or Mexican sugar.**—The green stalks of maize are full of sweet sap or juice. This, if boiled, gives a variety of sugar having all the characteristics of cane-sugar.

When the Spaniards first settled in America they found this variety of sugar in common use among the Mexicans.

This kind of sugar is not very extensively produced in other parts of the world.

In China a kind of sugar, known as **Sorghum sugar,** is produced from the "dhurra" plant; but it is produced and consumed entirely in that country, and has little interest for us.

III. The Manna or Leaf-Sugars

These differ from both grape and cane sugar. Most of them are exudations from the leaves of plants. There are many varieties of this kind of sugar, but they are all produced in very small quantities, and only in a few parts of the world. They are chiefly used for medicinal purposes.

Lesson XL

BEVERAGES—INFUSED DRINKS

Water is the natural drink of man and animals; but man in every part of the world concocts for himself artificial drinks of various sorts. These are nearly all of vegetable origin; they differ in the mode of preparation.

Call upon the class to name some of the commonest artificial drinks—e.g. *tea, coffee, cocoa; beer, wine, and ardent spirits.*

Put some dry tea, some coffee, and some cocoa into separate cups, and show how to prepare these beverages by adding boiling water. We make an **infusion,** i.e. *we steep the substance in boiling water; and this has the effect of drawing out the flavours and properties of the substance into the water itself.*

These may, therefore, be called **infused beverages.** They are always taken hot. The cup of tea is an **infusion** of the **leaves** of the tea-tree; the cup of coffee is an **infusion** of the coffee **bean or berry**; and the cup of cocoa or chocolate is an **infusion** of the **cocoa nib or seed.** In either case leaves, berries, and seeds have to be roasted and specially prepared before they are fit for use.

Beer, wine, and spirits are also prepared as **infusions**; but these infusions after being made are fermented. Hence these may be called **fermented beverages.** They are usually taken cold.

We will deal first with the infused drinks.

I. Tea

To us, as English people, tea is by far the most important of these beverages. But the consumption of tea is not limited to the people of England. The Russians and the Dutch are large consumers of tea and so are the people of the United States. Indeed **tea forms the daily drink of more people than all other beverages put together.** Probably not less than 500 millions of the human race depend upon tea, in some form, as their daily beverage.

Under the head of tea we include infusions made from the leaves of many varieties of plants in different parts of the world.

The tea with which we are familiar is **the leaf of the tea-tree,** originally a native of the hilly parts of Bengal and China. It is commonly known as **China tea.**

In South America a kind of tea, known as **maté** or **Paraguay tea,** made from the leaves of a species of holly, is the universal drink of all classes of the population.

In North America another kind of tea, known as **Labrador tea,** is made from the dried leaves of a plant that grows wild in those cold regions. It is the daily beverage of the native population.

The Arab tribes of Northern Africa make a very pleasant drink, possessing many of the qualities of China tea, from the dried leaves of a plant which is grown very extensively in those parts. It is known as **Abyssinian tea.**

Various other infusions are made from the dried leaves of plants, all of them resembling, in some respects, the tea with which we are familiar—*e.g.* **Tasmanian tea, Mexican tea, etc.**

All the tea used in this and other European countries came originally from China. The tea-plant of China has of late years been introduced for cultivation into India and Ceylon, and now the greater part of our supply comes from these countries.

The most striking feature in the tea-market of to-day is the daily growing favour in which the Indian teas are held, and the gradual falling off of the supply from China and Japan.

Our annual imports of tea amount to a total of about **200,000,000 lbs.** In the year 1882 India supplied about **54,000,000 lbs.** of this total.

Since 1885 Ceylon has given up the cultivation of coffee, and turned its attention to tea; and the Ceylon-grown tea is now making great headway in public estimation.

In 1892 the imports of Indian and Ceylon teas were greater than those of any other years by **22,468,000 lbs.**; while at the same time there was a falling off of the Chinese and Japanese product of **17,840,000 lbs.**

During the year 1893 the total amount of tea imported into this country from all quarters was **207,055,679 lbs.**

Let the class recapitulate briefly from their earlier lessons the leading facts connected with the growth of the tea-tree; the mode of gathering and preparing the leaves; and the different kinds of tea sold in the English markets.

In the island of Sumatra **the coffee-tree** is grown exclusively for its leaves, which are gathered, dried, roasted, and otherwise prepared, for the purpose of making tea—**coffee-tea**—the beverage universally drunk by the native Sumatrans.

II. Coffee

The beverage known by the general name of coffee **is prepared from the seeds of various plants.** Each variety of seed, however, requires the same treatment. They must be roasted and ground before they are fit to be infused in water.

Show some coffee-berries, raw as well as roasted, and some newly-ground coffee.

Let the class tell that the pleasant aroma and flavour are brought out by the process of roasting.

If time permit, the mode of roasting the berries should be recapitulated from the earlier lessons.

Coffee, in some form or other, is the beverage of **more than 100 millions of the human race.**

Most of the coffee of commerce comes from **the Arabian coffee-tree,** a tree indigenous to Abyssinia, where it grows like a wild weed. From Abyssinia the tree was first introduced into Arabia and Persia, and it has in later times been introduced for cultivation into various parts of both the Old and New World.

Most of our coffee now comes from Central America, Jamaica, and Brazil.

Till 1885 Ceylon supplied nearly all our coffee. But in that year the Ceylon coffee-plantations were stricken with the ravages of a disease which killed off nearly all the trees; and since then the cultivation of coffee has ceased in that island. The tea-plant has been introduced in its place, and **the coffee-tree has found a new home in Central America.**

The total imports of coffee into this country amounted during the year 1893 to nearly **30,000,000 lbs.**

III. Cocoa

Call attention to the cup of cocoa we made at the commencement of the lesson. Compare it with the tea and coffee, and show that it is not, like them, a simple infusion; it is rather a sort of soup or gruel than an infusion.

Lead the class to recapitulate, from the earlier lesson, the description of the tree and its fruit, **the cocoa-nib**; *the mode of preparing the latter; and its value as a beverage-making material.*

The Spaniards, when they first settled in Mexico, about the year 1500, found the cocoa-tree growing there, and the beverage in common use among the natives.

It is still **almost exclusively** grown in America and the adjoining islands. In the island of Demerara there are whole forests of these trees.

The consumption of cocoa in the United Kingdom has nearly trebled during the last ten years.

In 1893 we imported upwards of **31,000,000 pounds of cocoa.** Part of this is for home consumption; the rest, after undergoing various preparations, is sent out of the country again as a manufactured article.

Lesson XLI

BEVERAGES—FERMENTED DRINKS

I. WINES

Refer to the lesson on sugar. Call special attention to the variety known as **grape-sugar.** *We can see this sugar in the raisin. Let the class tell that grape-sugar is found not only in the grape, but in fruits generally. It is the sweetening principle of fruit.*

Take some ripe fruit—grapes, apples, pears, gooseberries, black or red currants. Squeeze them to press out the juice, and stand the juice in a shallow dish in a warm place. Within an hour or two the juice will begin to appear cloudy, and bubbles of gas will be given off from time to time. After a time the surface will be covered with a film resembling yeast.

The grape-sugar of the juice has, of its own accord, **commenced to ferment.** *During this fermenting process two new substances have been formed in the juice—one* **alcohol,** *the other* **carbonic acid gas.** *It was the carbonic acid gas that from time to time burst in bubbles on the surface of the fermenting juice. The presence of alcohol in the juice can be easily detected by its peculiar sharp, biting taste.*

If the juice were allowed to stand for a sufficient length of time, fermentation would continue, and more and more of **the grape-sugar** would be converted into **alcohol.** The juice would become actual wine.

This is the whole secret of fermentation. As the juice ferments, its grape-sugar becomes converted into alcohol.

It is no part of our business to follow up the process of wine-making any further.

Properly speaking, the name "**wine**" is used in a restricted sense for those drinks made from the fermented juice of the grape; but wine is made from most fruits.

There are many varieties of wine, according to the kind of grape and the mode of preparation.

The wine-countries of Europe are France, Spain and Portugal, Germany, Italy, Hungary, Greece, and Turkey; and in all these the cultivation of the vine and the manufacture of the grape into wine constitute most important national industries.

From France we get **Champagne, Médoc, Burgundy,** and **Bordeaux.** Spain supplies us with **Sherry** and **Malaga**; Portugal with **Port.** The wines of Germany are produced in the basin of the Rhine. They are commonly known as **Rhenish wines. Moselle** is also a German wine.

Madeira, a wine resembling sherry, comes from the island of that name; and the chief of the Hungarian wines is **Tokay.**

Some wines are bottled while the fermenting process is going on. They still contain carbonic acid gas. It is this gas in the wine which causes it to foam when uncorked, and gives the wine its brisk taste.

Such wines are known as **sparkling wines.**

Some wines are not bottled until the fermenting process is completed. In the case of these the carbonic acid gas is given off before they are put into the bottle, and they do not continue to work and foam. These are known as **still wines.**

The total quantity of wines of all sorts imported into this country in the year **1893** was **14,538,048 gallons.**

Other wines.—Among the wines made from fruits other than the grape are the home-made wines, such as currant, gooseberry, raspberry, orange.

Cider and Perry.—The juices of the apple and the pear are fermented and made into a kind of wine. That

made from the apple is called **cider**; that from the pear is **perry**. Both are largely produced and consumed in England, France, and North America.

Palm-wine or Toddy.—Most of the palms yield a sweet juice, which if allowed to ferment will produce an alcoholic liquor. **Toddy** is a kind of wine made from the juice of the topmost spathe or flower-shoot of the **cocoa-nut palm.** It is made and consumed in large quantities in all countries where this palm grows.

A somewhat similar wine is made from the **date-palm.** It is known as **date-wine,** and is highly esteemed by the people of the desert where this tree grows.

II. Beers

Lead the class to tell that the starches can be made to yield a sort of **sugar,** *called* **maltose,** *which is used in brewing.*

This sugar differs from the **grape-sugar** of fruits.

What happened to the fruit-juice which we allowed to stand in the dish? The grape-sugar in it at once began to ferment.

The starch-sugars will also ferment if dissolved in water, **but only after some yeast has been added to the solution.**

This constitutes the difference between wines and beers. Wines are made from **grape-sugar** which **ferments spontaneously**; beers are made from sugar **which requires yeast to make it ferment.**

As in the case of wine, the fermenting splits up the sugar into **alcohol** and **carbonic acid gas.**

Barley is the usual starch grain for brewing purposes.

The barley is first converted into **malt** by the **maltster.** He soaks the barley in a tank of water for two days, and then lays it out evenly on the floor of the malt-house in a warm temperature. After about a fortnight the grains are seen to be **sprouting.** They are then, in this state,

thrown into an oven or kiln. The heat **stops further growth,** and the **starch** is converted into **sugar.** In this condition the grain is called **malt.**

We have nothing to do with the process of beer-making. It will be enough for us to know how the barley-grain is converted into **malt.**

Show some hop-flowers. Explain that hops are used in brewing. They give to the beer its bitter, aromatic flavour, and also prevent it from turning sour. Beer made without hops will not keep long.

Hops are very largely grown in England. The hop-gardens of England extend into fifteen counties, and occupy no less than **71,789 acres.** The chief county for hops is Kent. Germany, Australia, New Zealand, the United States, and Canada are all hop-producing countries.

Nearly one-third of the hops grown in the world are consumed in Great Britain.

Describe the hop-grounds in the flowering season. The plant itself is a climber, with a weak, slender stem. Tall poles are provided to support the plants—the tendrils (like the tendrils of a vine) clinging to and clasping the poles. When the clusters of flowers are in their beauty, a hop-ground presents a picturesque sight—it is often called the English vineyard.

Beer can be and is made from other grains as easily as from barley.

Rice-beer or **saké** is the common drink of the Japanese to-day; and **rye-beer** is largely made and consumed by the Russian peasants.

Maize-beer or **chica** was a common drink among the Indians of America when the Spaniards first settled in that continent, and it is still in use there and in the neighbouring islands.

The common mode of preparation is disgusting in the extreme. All the members of the family seat themselves round the room, with a large bowl or **calabash** in the middle. Each takes a handful of maize and chews it, depositing it when properly chewed in the calabash. When there is enough it is stood aside to ferment, and the

drink they make of it is (in spite of its revolting preparation) very highly prized.

III. Ardent Spirits

Fit the neck of a retort into the mouth of a glass flask, with a good cork to keep it air-tight. Put some water into the retort, and fix the retort in the stand over the Bunsen burner, letting the flask attached to it lie in a basin of ice. If the water in the retort be now left to boil, the vapour from it will rise and pass along into the flask. The class are quite familiar with the operation.

Call upon them to tell what happens, and to explain why the vapour condenses in the cold flask.

This is the process of **distillation,** and the water which has been collected by condensing the vapour in the flask may be called **distilled water.**

If a fermented liquid is boiled in a closed vessel, not only the water-vapour, but all the alcohol in the liquid will rise and pass away as the vapour did just now; and if the alcohol and water-vapour can be conducted by a pipe into a cold receiver, condensation will take place, and they will again assume the liquid form; **they will become a distilled liquid.**

In this way wine is distilled and made to yield the spirit **brandy**; fermented molasses is distilled and made to yield **rum.**

The liquor of malt when distilled in a similar way yields **whiskey.**

The sugar from potato-starch is distilled in France and Germany into a fiery spirit known as **potato-brandy.**

N.B.—*The teacher should be careful to impress upon the class that our only object in dealing with these intoxicating drinks here is to point out the materials from which they are made, and to give a general notion of their preparation. We have nothing to do with them in themselves. Whatever good they may have done, it is certain they have done untold mischief, and that man is wisest who has nothing to do with them.*

Lesson XLII

PLANT-FIBRES FOR SPUN AND WOVEN GOODS

Call upon the class to tell the various plant-fibres used for making materials for clothing and other textile goods—e.g. *cotton, flax, hemp, jute.*

What is the meaning of "textile"?

Refer to the former lessons, and lead the class to describe briefly and in a general way the processes of **spinning** *and* **weaving.**

I. Cotton

Let the class name some of the materials made from cotton, such as calico (cotton cloth), nankeen, muslin, fustian, hosiery, and lace.

Explain that "fustian" is the common name for a large number of heavy materials, used principally for working-men's clothing—e.g. *corduroy, moleskin, fustian, velveteen, velveret, beaverteen.*

"Hosiery" originally meant "stockings." Now the name includes all those textile fabrics made by a kind of knitting or chain-stitch, entirely different from the regularly crossed threads of woven materials.

Cotton supplies materials for clothing man in all parts of the world. Indeed, the cotton-plant may justly take its place among the most valuable of Nature's products. It is by far the most abundant and most important of all materials used for textile goods.

1. **The cotton-plant** grows in most of the hot countries of both the Old and the New World.

There are three varieties of the plant—the tree, the shrub, and the herb.

The cotton-tree grows to the height of from 15 to 20 feet (2½ to 3½ times as high as a man). It yields the

finest and most valued cotton. It grows on the shores of Florida and the adjoining islands. Hence it is sometimes known as Sea Island cotton.

Its down consists of long, silky, but strong fibres. This cotton is known by another name as "**long-staple" cotton.**

The cotton-tree grows also in India, China, and North Africa. The Hindoos make from it a fine silky cloth for turbans. The cotton-shrub is a woody perennial plant, about the size of our currant-bush.

Most of the cotton grown in the United States of America is of the herbaceous variety. The seeds are sown in March and April; the plant grows to the height of about two feet; bears bright green leaves; and blooms in June.

The flower is very like our hollyhock, and when it falls it leaves behind **a pod about the size of a walnut,** containing seeds embedded in a loose white woolly down—the cotton of commerce.

The cotton is picked by hand in the autumn by women and children, who go through the plantation from plant to plant with bags or baskets slung round their necks.

2. **Its commercial value.**—Some idea of the commercial value of this product may be formed from the following facts:—

It is estimated that in this country alone no less a sum than **£100,000,000 sterling** is sunk in the manufacture of cotton goods.

There are not less than **half a million looms** at work in our cotton centres; and in a busy time **10,000,000 yards of cotton cloth can be turned out in one day.**

The fact that from **£60,000,000 to £40,000,000 sterling** are paid annually in wages and the cost of working will speak as to the number of persons employed in the manufacture.

In 1886 we imported **671,026 tons of raw cotton;** and the same year we exported cotton-yarn to the value of **£11,500,000,** and cotton goods to the value of

£57,000,000 sterling, besides what is retained for our own use.

Before the cotton down is fit for the manufacturer the seeds must be removed. The seeds are about the size of grape-seeds, and contain much oil.

This oil is expressed, and forms an important article of commerce—**cotton-oil.** It is used for burning in lamps, for oiling machinery, for soap-making, and as a substitute for olive-oil. The residue after the oil is removed forms a valuable oil-cake for feeding cattle.

II. Flax

Show some raw flax, and some specimens of the manufactured article. Call upon the class to describe the plant, and the nature of the bast-fibres or lint which supply the material for the manufacturer.

Let them name as many as they can of the goods manufactured from flax, the teacher assisting where necessary—e.g. *linen, duck, diaper, damask, sheeting, towelling, huckaback, drill, check, drabet, sail-cloth.*

The rougher and commoner fibre is made into sacking; and a mixture of flax with cotton gives the useful fabric—**union.** The plant yields another product besides the bast-fibres of the stem. The seeds form a valuable article of commerce. When pressed they yield linseed-oil (useful for its drying properties) and oil-cake for feeding cattle.

The mode of cultivation depends entirely upon whether **the fibres** or **the seeds** are the chief product in view.

The plant will grow in warm as well as in temperate climates. Warm climates produce **the finest seeds**; temperate climates **the best fibre for the manufacturer.**

The flax-plant is extensively grown in the north of Ireland; but we import every year upwards of **100,000 tons of foreign flax,** more than half of which comes from Russia. The rest is supplied by Belgium, Holland, and North Germany. Although Russia sends the largest supply, Belgium gives the finest quality of fibre

The chief flax-markets in this country, and the chief centres of the flax and linen trade, are Belfast for Ireland, Dundee for Scotland, and Leeds for England. Ireland is by far the most important of the three countries as regards this trade.

In addition to what is retained for our home consumption, we export annually about **200 million yards of linen and other flax fabrics,** besides immense quantities of yarn, and thread for lace and sewing purposes.

During the year 1893 the total value of our linen manufactures amounted to **£4,165,902**; linen-yarn alone to the value of **£890,124** was produced.

III. Hemp

Let the class, as before, tell all they can of the nature of this plant and its products—the uses to which the fibres are put for making rope and cordage, canvas, sacking, sail-cloth, floor-cloth, and other coarse, strong fabrics. Show its close resemblance to flax, as a material for spun and woven goods.

Most of the hemp used in our manufactures is imported from foreign countries—chiefly from Russia, India, the Philippine Islands, Holland, Germany, and the United States.

In addition to the bast-fibres of the stem, the hemp-plant yields oil (somewhat similar to linseed-oil). The seeds after the oil is expressed forms oil-cake.

We annually import about **1,000,000 cwt. of hemp** from all sources.

IV. Jute

The class should again be made to tell what they can remember of this substance, its growth and production, as a raw material. It is not a plant of English growth. It grows chiefly in India, and has very rapidly come into prominence as a material for textile fabrics.

It was practically unknown in this country till the year

1840. Now its importance may be seen from the fact that during the year 1893 we exported jute-manufactured goods and yarn to the value of **£2,848,283,** in addition to what was kept for home use.

Our annual imports of raw jute fibre from India alone amount to upwards of **300,000 tons.**

Jute is cheap, it is easily worked, it has a glossy appearance, but it has not the strength and durability of flax or hemp. Dundee is the head centre of the jute manufacture in Great Britain.

ECONOMIC PRODUCTS OF ANIMALS

Lesson XLIII

ANIMALS USEFUL FOR FOOD

I. Bread and Flesh compared

In dealing with the vegetable food-stuffs we took bread in some form to be man's staple food.

We commenced our investigation of these vegetable foods by examining the composition of **wheaten bread,** and we found that every kind of bread must contain similar materials and possess similar nutritive qualities.

Call upon the class to give the composition of wheaten bread and to describe the properties of its constituents, as far as they can.

We shall now follow the same plan in dealing with flesh-foods, taking **a piece of lean beef** for our first investigation. If we get a piece of newly-cut lean beef fresh from the butcher, we find that it is **moist.** This is due to the **water** which the flesh contains. We must get rid of this water before we can learn anything about the

composition of the beef. The best plan is to let it dry slowly on a "tin" plate in the hot sun. The water will evaporate gradually, leaving the meat dry. Or it may be placed in a warm, but not hot, oven.

As the drying goes on the beef **shrinks** considerably in size. In fact if the original piece weighed **a pound,** we should have, after the drying, **less than a quarter of a pound** of perfectly dry flesh. That is to say, **three-quarters of its weight** is **water.**

We can find out by experiment what are the constituents of the dry flesh.

Take a similar piece of beef. Call attention to its **red** *appearance. Why is this? It is the* **blood** *in the beef which makes it red. We can get rid of most of this blood by repeatedly washing it in fresh water, and the beef will at last* **lose the red colour.** *It will be seen to consist of a mass of* **whitish fibres or threads,** *with little particles of fat interspersed among the fibres.*

If this be put into spirits of wine, the fat will be all dissolved out of it and nothing will remain but the **fibrous tissue.** *This is the principal solid constituent of the muscles (or lean flesh) of animals. It is known in the scientific world as* **myosin.**

When we eat beef it is this part of it (**myosin**) that becomes **flesh-forming** (or tissue-forming) **food.**

It is the nutritive part of flesh-food as **gluten** is of vegetable food. In fact, **myosin** of flesh and **gluten** of the vegetable may be considered as identical in this respect.

Have the composition of lean beef and wheaten bread set out side by side on the black-board for comparison.

Wheaten Bread.			Lean Beef.		
Water	40	parts	Water	77	parts
Gluten	7	,,	Myosin . . .	19	,,
Fat	1	,,	Fat	3	,,
Starch	50	,,			
Mineral matters .	2	,,	Mineral matters .	1	,,
	100			100	

Comparing 100 pounds of beef with 100 pounds of wheaten bread, where do we find the great difference in their composition? The bread contains **half its weight** of **starch**; the **meat** has **no starch**; the meat contains nearly **three times as much flesh-forming material** as the bread.

The composition of most kinds of flesh which we eat as food is very similar to that of beef.

II. Different Kinds of Animal Food

Civilised man in all parts of the world has always reared and kept certain animals for food. To distinguish these from wild animals of the chase, we speak of them as domesticated animals. The chief of them are the ox, the sheep, and the pig.

The cow not only provides us with **flesh-food** when dead, but also while living gives **milk**, which is in itself a valuable food. We use it in its simple form, and we convert it into **butter** and **cheese.**

Call upon the class to give, as far as they can, the composition of milk, butter, cheese, and tell their nutritive value. Compare them with wheaten bread and beef.

The flesh of the sheep is eaten only as fresh mutton; the pig's flesh is not only eaten fresh, but it is salted, smoked, and cured into **bacon** and **hams.**

III. Sources of Supply

Although our British farmers rear very considerable numbers of live stock, we depend very largely upon foreign supplies. We import the **living animals**, as well as **dead carcases** of beef and mutton.

In the year 1886 the value of the **live animals** alone imported into this country for food was **£7,143,430 sterling.** Most of our live cattle are sent from **Holland, Denmark,** and **North Germany.** Our imports of

carcases of beef during the same year (1886) reached **£2,187,576**; and of fresh mutton **£1,404,888.**

Tell of the modern plan of freezing the carcases whole, and so sending them thousands of miles across the sea without fear of their going bad.

Describe the **refrigerating chamber** *on board the ship, filled with hanging carcases. The carcases themselves become frozen, and in this state would keep for almost any length of time. This invention has been a great boon to the poor.*

Describe the great **sheep-farms** *of* **Australia** *and* **New Zealand**—*the sheep there being reared and kept solely for their* **wool,**—*the dead carcases are of little value. Hence they can be frozen, shipped to England, and sold in our markets at marvellously low prices.*

Call attention to the **"tinned" meat,** *and explain why this can be bought so cheap. The farmers of Australia and New Zealand used to throw away as refuse what they now put into these tins and send to England. The carcases are thrown into great coppers, and boiled for the sake of the* **fat** *or* **tallow.** *When this is removed the remainder is closed up in tins for food, and very good wholesome food it makes.*

In addition to our home production of butter and cheese, we imported in 1886 **cheese** to the value of **£3,867,896**; and **butter** and **butterine** worth **£8,140,188** and **£2,958,300** respectively.

Our imports of **bacon** and **hams** for the same year (1886) amounted to **£8,379,342**; the amount from the United States alone reached the sum of **£6,291,607** (about three-fourths of the whole).

If time permit, a very graphic picture might be drawn of the great cattle and hog market of **Chicago.**

Outside the city itself are the **State slaughtering-yards.** The animals are brought to the yards alive, and slaughtered and prepared with lightning speed for the markets of the world.

In 1890 **two million cattle, a million sheep,** and **five million hogs** were killed and dressed in these yards —an average of **25,000 animals each day** of the year.

The most marvellous sights are to be seen in the hog-yards. The hogs are driven, about 20 at a time, into a square room, where a man despatches them by a single blow with a heavy hammer between the eyes. Instantly they are dragged, stunned as they are, through a doorway to make room for 20 more, and while this second batch are being knocked over, men are busy cutting the throats of the first 20, and so on.

By the time the second 20 are stunned, the first batch, in the other room, have bled sufficiently, and they are then slid down into the scalding tank. They are pushed through this tank by men with long poles, **in exactly two minutes from the time they entered it.** At the other end they are lifted out, by a crane and placed upon the scraping table.

Men are stationed round the table, to perform the **scraping process.** No less than **five hogs every minute** must pass through their hands and be scraped clean of hair and bristles, because other batches are continually coming up to take their place.

From the scraping table the carcases are hoisted on eight large hooks placed round the circumference of a great horizontal wheel ten feet across. The wheel moves round perpetually by steam, **each revolution occupying exactly one minute.**

As soon as the hog is hoisted on the hook, the wheel begins to move. It turns one-eighth of its circumference, and pauses, **while another hog is swung on the second hook.** While this has been going on, two men at the first hook have been busy dashing clean water over the carcase to remove any loose hair or dirt.

The next turn of the wheel means **a third hog hoisted** and the second taking the place of the first. This one has been passed round to another man, who slits open the carcase and removes the intestines like lightning. Another turn, and another, and so the wheel revolves, each man at his station taking his share of the work, **which he is compelled to perform in twelve seconds,** because as

one hog is removed from the wheel, another is added, and there are only five hanging at the same time.

The carcases, properly cleaned, are at last removed to the cooling house, where several thousand hogs may be seen hanging to cool at the end of the day's work.

Poultry, eggs, and game form important items in our animal food. In addition to our home-supply we import poultry very largely from other countries, especially from France. In 1886 we spent on eggs alone £2,879,000, most of the eggs coming from France.

Fish of various kinds must be reckoned among the important articles of our food-supply; and the fisheries of Great Britain are a source of great wealth to the country.

The cod, herring, mackerel, salmon, haddock, and pilchard are among the most valuable catches; and oyster-cultivation is prosecuted on various parts of the coast.

The **herring-fishery** is carried on chiefly **round the Scotch coasts**; the **pilchard-fishery** is confined to the **south-western corner of the island.**

In 1887 it was estimated that **125,000 men** and **32,000 boats** were actively engaged in the British fisheries. The most valuable of the British fishing-grounds is the **Dogger Bank,** between England and Holland.

Among the most important and productive fisheries of the world are those of Newfoundland, Nova Scotia, and New Brunswick. Cod is the chief fish caught, but the Gulf of St. Lawrence absolutely teems with many varieties of fish. The annual value of these Canadian fisheries varies from four to six millions sterling.

Lesson XLIV

WOOL OF THE SHEEP

I. Properties of Wool

Lead the class to talk about the coverings of various animals, especially with a view to show that all are provided with exactly

the kind of covering suitable to the climate and conditions under which they live.

In the extreme frozen north all animals are clothed with a thick warm fur coat; in the temperate regions the fur gives place to wool, as in the case of the sheep; in tropical climates the animals are for the most part provided with a covering of thin scanty hairs.

Of all these animal-coverings wool is by far the most useful to man.

Show some specimens of wool, and side by side with them some bristles, horse-hair, cow-hair. All these are varieties of the hairy coverings of certain animals.

Call special attention to the bristle, and lead the class to describe its coarse, stiff structure and smooth shiny appearance. Compare it with the **fine, wavy, curly** *nature of the* **fibres of wool.**

Explain that if the wool were examined by the aid of the microscope, it would be found to have **a rough, scaly surface,** *totally different from the smooth surface of the bristle.*

It is easy to distinguish between the wool-fibres and the bristle, because we are taking as illustrations the two extremes of these animal coverings; but the difference we have noticed constitutes the general distinction between wool and hair of all sorts. It is the peculiar **wavy, scaly characteristic of wool that renders it valuable to the manufacture of textile fabrics.**

II. Varieties of Wool

Wool is usually classified according to the length of its fibres. The "**short-fibre**" or "**short-staple**" wool is **very wavy,** and contains **a large number of scales**; the "long-fibre" or "long-staple" wool is less curly and has fewer scales, and at the same time it is coarser in its texture.

In the rearing of sheep different treatment is necessary, according as the end sought is fine mutton or fine wool.

In this country sheep are reared with a view rather to their flesh than their wool, and the consequence is that as a rule English wool is inferior in quality to most of the foreign varieties.

Our manufacturers have to depend largely on imported material, most of which is supplied by our own colonies, especially Australia, New Zealand, South Africa, and India.

Our English sheep include, among the short-woolled varieties, **the Dorsets** and **the South Downs.** The latter are a small breed noted for the **fineness of their wool** as well as for the **quality of their flesh**; they are the most highly-prized of the pure English breeds.

Among the long-woolled kinds **the Leicestershire** and **Cotswold** breeds are considered the best.

Besides these pure breeds there are several well-known cross-breeds.

The average weight of the fleece of an English sheep is from 5 to 7 lbs.; but the quantity as well as the quality of the wool depends entirely on the breed, the climate, the soil, and therefore upon the sort of food available.

Among the foreign breeds **the merino sheep stands first** for the excellence of its wool, both as regards fineness of texture and the number of curves and scales on its surface. The true merino sheep is a handsome animal, **the female as well as the male being horned.**

The merino sheep was originally a native of Spain, but has been introduced into nearly every sheep-rearing country in the world. Wherever these sheep are bred they are highly cultivated, the principal object being wool. **The merino sheep of Saxony and Hungary** are especially famous for both the quality and the quantity of their wool. The fleece of the Saxon merino ram is never less than 7½ lbs. in weight, and it frequently reaches as much as 15 lbs.

These sheep have been introduced into England, and have greatly improved the English breeds. They have also been extensively introduced into Australia, New Zealand, and South Africa.

The continental varieties are tended with great care, housed in stables during the night, and protected at all times from the inclemency of the weather. The sheep are frequently washed, not only in cold, but in hot water and soap. The wool is very highly prized, and the sheep instead of being killed off for mutton are allowed to live for ten or twelve years for the sake of their annual fleece.

Among the other varieties of sheep are the broad-tailed sheep of Asia Minor, Tartary, and Northern Africa. The heavy tail of this sheep is a mass of fat, often weighing as much as 20 or 30 lbs. This tail is considered as a great delicacy for the table, and so much trouble is taken to preserve it from injury, that a small carriage is harnessed to the animal for the purpose of supporting it. This sheep is invaluable to the people of those regions. Its milk and its flesh supply them with food, and its wool, although very coarse, provides material for clothing.

III. The Wool-Trade

Next to cotton, **wool** is by far **the most important material** employed in the manufacture of **textile fabrics**. The woollen manufacture in the United Kingdom is estimated to give direct employment to **more than a quarter of a million operatives**; while the number of persons indirectly engaged in and for all the branches of the trade, from the time the wool leaves the farmer to the production of the manufactured article, is **fully a million**.

Our annual home-supply of wool ranges from about 160 to 200 million pounds in weight. In addition to this we import every year from 500 to 600 million pounds of foreign wool, at a cost of about £25,000,000 sterling.

Our Australian colonies supply the largest share of this, and every year marks an improvement in Australian wool, both as regards quality and quantity. It is estimated that the sheep-runs of New South Wales alone feed upwards of 30 million sheep.

Lead the class to picture those immense grassy tracts, many miles in extent, the sheep on a single "squatter's" run being usually numbered by hundreds of thousands. Think of the shearing time on those runs. The work of shearing is one of the most important to the farmer, as it must be done at the proper time, and there is great demand for the men.

IV. The Woollen Manufactures

The total value of our woollen manufactured goods averages about **£100,000,000 sterling** each year. It is estimated that we retain for home use about three-quarters of this output; the rest is exported.

There are several branches of the woollen manufacture.

1. **Broadcloth.**—This includes, not only what is commonly known as broadcloth, but all the varieties of the "felted" cloths, such as kerseymere, and the cloth used for livery uniforms.

Show some samples of the different cloths.

It differs from all other fabrics in being "felted" or "fulled." The man who does this is called a "fuller," and the object of the "fulling" is to mat the threads of the woven fabric together into a mass, so as to destroy the appearance of the warp and woof of the weaving, and to produce a smooth "nap" on the surface of the cloth.

This felting tendency of wool may be illustrated by reference to a flock bed. The flocks are, of course, wool; and it is well known that if the bed is not frequently shaken up, the whole will soon become matted into hard knotted lumps.

The "short-staple" wool, with its numerous scales and curls, is always employed in the manufacture of broadcloths.

This branch of the manufacture is carried on in Gloucestershire, Wiltshire, and Somersetshire, and is known as the West of England broadcloth trade; it is also an important part of the woollen manufactures of the West Riding of Yorkshire.

2. **Worsteds and stuffs.**—These goods are made of

the combed fibres of the "long-staple" wool, and are easily distinguishable from the woollen cloths just mentioned.

Show a few samples of these materials.

The manufacture of worsted goods is carried on at Bradford, Halifax, Leeds, and York, and in Worcestershire and Norfolk.

It is estimated that there are in the United Kingdom no fewer than **650 factories** engaged in this work, employing about **120,000 operatives.** We export annually worsted goods to the value of over **£21,000,000 sterling,** and this probably represents about one-half the entire production.

The worsted trade was first introduced into England in the Middle Ages by some Flemish weavers who settled in the little Norfolk village of Worsted. Hence the name has been given to this class of goods.

3. **Hosiery** is extensively made in Leicestershire; and

4. **Woollen yarn** is spun at various towns in the West Riding of Yorkshire and at Lancaster and Derby.

5. **Carpets.**—Several varieties of carpets are manufactured in the United Kingdom; such as Brussels, tapestry, Wilton, Kidderminster, Axminster, druggets, and felts. Felts are usually made from cow-hair felted together.

Show some specimens of as many of these as possible. Call attention to the backing of the Brussels and the tapestry.

The body or backing of Brussels has **strong linen threads** for both warp and woof; the backing of the tapestry is woven from **cheap yarn** often made of cotton waste. A Brussels carpet is therefore much more serviceable than a tapestry.

In Scotland the woollen manufacture is confined to tweeds, plaids, and woollen shawls.

6. **Shoddy and mungo.**—*Lead the children to tell what happens to our clothes when they become old and worn out. They are cast off and sold to the rag-merchant. Let us follow these rags and see what becomes of them.*

The rag-merchant sells these woollen rags to the shoddy

manufacturer. The rags are first thoroughly cleansed, and then torn up by machinery into shreds or "flock," as it is called. The flock is spun into new yarn, and woven into new cloth for further use.

This shoddy manufacture is carried on very extensively at **Batley, Dewsbury,** and at most of the large manufacturing towns in the West Riding of Yorkshire.

It is estimated that in these shoddy factories no less than **50,000,000 lbs. of useful material** is produced every year from these woollen rags, which were formerly cast away as waste. In addition to our own waste rags, we import further supplies from foreign countries amounting to nearly **60,000,000 lbs.** to be torn up and re-manufactured.

Point out that this is a great boon to the poor in providing cheap clothing, and why.

There are two classes of these re-manufactured materials. One is made from worn-out woollen rags of all sorts—worsted stockings, flannel, carpet, shawls, stuffs. This is known as **shoddy.**

The other, and better kind, is made chiefly from tailors' cuttings and old broadcloth. This is known as **mungo.**

7. **Flock wall-papers.**—There is one other very interesting branch of manufacture in connection with waste woollen rags.

The wool for this purpose is torn up, ground very fine indeed, and then sifted to remove all large particles. It is then dyed various colours, and powdered over the newly-varnished surface of the most elegant and expensive wall-papers—the powdered "flock" producing the beautiful "velvet" or "flock" pile, which makes them resemble richly-figured tapestry.

Lesson XLV

OTHER WOOL

I. Introduction

In our last lesson we investigated the general properties and varieties of wool, and the leading facts connected with the woollen trade and manufacture. But we examined only the wool of the sheep, and, generally speaking, whenever we think of wool, it is sheep's wool that we mean.

Many other animals besides the sheep yield valuable wool. The object of our present lesson will be to examine these wool-bearing animals and their products one by one.

II. The Goat

1. **The Angora goat.**—The most important of the wool-bearing goats is the **Asiatic goat,** more properly called the **Angora goat.** It has a long, white, silky fleece which is clipped annually, and averages from 2 to 3 lbs. in weight.

Angora wool is largely in demand; our annual imports reaching, on an average, **7,000,000 lbs. weight,** and being valued at **£1,000,000 sterling.** It is known here as "**mohair,**" and is valued according to the length and fineness of its staple, and the softness and silkiness of its appearance.

The manufacture of this wool is confined to the West Riding of Yorkshire.

The Angora goat has been transported from its original home into many parts of the world, and is now successfully reared in South Africa, several of the Australian colonies, and the United States, especially in the western or Pacific states. In all these places the stock is increasing rapidly, as these animals are exceedingly prolific.

Closely allied to the Angora goat are the **Thibet, Persian,** and **Circassian goats.** Indeed, all four are one and the same animal, differing only according to the varying conditions under which they live.

The Thibet, more generally known as **the Cashmere goat,** has long been famous for the soft, downy silkiness of its wool. The best of it is known as "pashum" or shawl wool, and is manufactured locally into costly shawls.

Much tedious care and labour are bestowed on the production of these shawls, each part of the process being allotted to separate individuals. Indeed it is said that the manufacture of **one pair of shawls** has been known to occupy **every member of a shop for a year and a half.**

As a consequence of this, these Cashmere shawls are very costly. The production of a single shawl often represents as much as £600 or £700; and Eastern potentates always bestow them upon their most distinguished visitors as a special mark of their favour.

2. **The Llama.**—*Show a picture of this animal. Tell that it is a native of South America, where it is used as a beast of burden, especially in Peru. Even the cottagers there have their little flock of these animals (perhaps a dozen or more) to carry their goods to market, while the merchants usually drive them with their burdens in flocks varying from* 500 *to* 1000.

The llama-wool is not exported, being much in demand locally for the manufacture of carpets, sacking, and ropes.

The llama family include, in addition to the llama itself, the **alpaca,** the **vicuna,** and the **guanaco.**

Of these the most important by far, as regards the wool, is the **alpaca.**

The fleece, which is shorn annually, averages from 7 to 12 lbs. in weight, and is superior to the wool of the sheep for the length and softness of its fibre.

The Peruvians set such high value on this animal that they long guarded it with jealous care. The consequence was that the value and beauty of alpaca wool was quite unknown to Europeans till quite recent years.

Sir Titus Salt introduced it into this country, and set

up the manufacture of alpaca goods in the village which has since been called from his name **Saltaire**, and is to-day a flourishing town.

Our annual imports of alpaca wool now average from **4,000,000** to **5,000,000 lbs. weight**, and the alpaca manufacture ranks as one of our staple industries.

The wool of the vicuna and guanaco is not yet imported to any large extent into this country, although vicuna wool is said to be superior even to that of the alpaca.

3. **The Camel.**—*Lead the class to tell all they can of the camel as an animal specially suited by nature for the regions where it is found. Describe its use as a beast of burden, where most other animals would fail. Tell of the nature of its hump, and of its power of holding water in its stomach, for future use, pure as when it was drunk. Describe the wide-spreading cushion of the foot, and its adaptation to the sandy tracts over which it travels.*

It has powerful teeth for masticating the rough, prickly vegetation, which is the only sustenance it can find on those wastes of sand. Its eyes, ears, and nostrils even are specially protected against the clouds of loose shifting sand which often fill the air.

The wool of the camel is shorn every spring; that of the two-humped camel being highly valued for the soft silkiness of its staple. It is made into various costly articles — shawls of the camel's wool often fetching as much as £180.

Camel's hair is imported into this country mostly for the manufacture of delicate brushes or pencils for painting.

Lesson XLVI

LEATHER—HIDES

I. Structure of the Skin

The skins of various animals provide the material for making leather. Before we can properly understand what

leather is and how it is made, we must know something of the structure of the skin itself.

. *Refer to some of the earlier lessons, and lead the children to tell what they can of the structure of their own skin. If they understand that, it will be quite sufficient, for all skins are almost identical in structure.*

What can you tell of the structure of your skin? It is composed of two layers, one above the other.

What are they called? The outer layer is called the **scarf-skin, epidermis,** or **cuticle**; the under layer is the **true skin, dermis,** or **cutis.**

When can these two layers be distinctly seen? When the hand or foot is blistered: the outer cuticle then becomes raised up and separated from the true skin.

What is the appearance of this blister? It is a thick, tough, horny layer. It may be cut away without giving pain or drawing blood.

Run a needle through the epidermis of the hand, and show that it is insensitive to pain, and that it does not bleed. Why?

The cutis or true skin is composed of a mass of fibres crossing and recrossing each other in all directions, the spaces between the fibres being filled up with **gelatine,** nerves, and blood-vessels. We usually speak of it as **fibrous tissue.** It is this fibrous tissue of the true skin which provides the material for leather.

If a skin be taken from an animal and thrown aside in a damp place, it will soon begin to smell badly and decay, for **the gelatine in it has a strong tendency to putrefy** when wet. But if the skin be at once hung up in a dry place, it shrinks and becomes horny and stiff, as the gelatine in it dries and hardens.

Compare a piece of leather with a skin that has been merely dried in this way. The leather is **waterproof**; *the dried skin, as soon as it became soaked with water, would not only be soft and porous, but it would actually begin to putrefy.*

A rabbit-skin might be very easily prepared for the lesson. All that is necessary is to scrape away the fleshy and fatty particles adhering to the skin, stretch it out with a few tacks upon a

board, fur downwards, and rub the skin with a mixture of powdered alum and salt repeatedly for a few days. The skin thus prepared should be shown, and the change from a mere skin to actual leather should be explained to the class.

The gelatine in the skin absorbs the alum and salt, the result being that the combination makes a new substance—**leather**, which **has lost its tendency to putrefy, has thickened** considerably, and at the same time **has become waterproof.**

II. The Manufacture of Leather

The skins of animals used for leather are known as **hides** or **pelts.** It must be carefully borne in mind that only the **fibrous matter** of the **true skin** is of use to the manufacturer. The hair, the whole of the epidermic layer, and all particles of fat and flesh must be removed. This is the first process in the manufacture.

1. **Preparing the skins.**—The hides are first soaked for about a fortnight in water; after which they are taken out and thrown into tanks or vats of **lime-water,** where they are allowed to remain for about ten days. The lime has the effect of loosening the hair and the epidermis on one side, and the fat and flesh on the other.

When they have been soaked sufficiently they are taken out and **scraped with knives** on both sides to remove all these useless parts.

The next thing is to get rid of every particle of the lime, for that would be injurious. This is usually done by soaking the hides for about a week in tanks containing **fowls' dung and water.** This solution absorbs all the lime from the skins and leaves them soft and supple. They are now ready for the next process.

2. **Tanning.**—The bark of many trees contains a peculiar substance called **tan** or **tannin.** The best tan is obtained from the bark of the **oak** and **hemlock,** but other kinds are sometimes used. A preparation is made

by grinding the bark in a mill, and steeping the powder in water.

The prepared hides are thrown into the **tan-pits** (deep tanks in the ground) filled with the prepared bark-liquor, which is known as **ooze,** and there they are left to soak for **four** or **five months.** The object is to make the **tannin of the bark** unite with the **gelatine of the skins.** This converts the skins into actual leather. The longer they are allowed to remain in the tan-pits the better, for it is necessary that every particle of the gelatine shall be acted upon by the tannin, if the leather is to be of good quality.

3. **Currying.**—The hides when sufficiently tanned are taken out of the pits, washed and laid out to dry in open lofts, after which they are hammered and rolled between heavy rollers to harden them.

Some of the thicker skins are split into two by machinery, but the flesh or under side is inferior in quality to the upper or hair side of a split skin.

The thin skins which are required for upper leathers of boots are dressed with oil and tallow, and rubbed to give them a smooth surface; they are then blacked with lamp-black and tallow, and rubbed and smoothed and polished again. This process is known as currying.

III. Trade in Leather

We have seen that the skins and hides of different animals vary in thickness and quality, and the leather made from them receives different names, and is applied to different purposes accordingly.

There is great variety of quality even in the different parts of the same hide. The skin, as it is taken from the animal, is styled the "**crop**" or "**full hide.**" After it is tanned and dressed it is cut up into the "**butt**" and the "**offal.**" The "butt" is the best portion of the leather; the "offal" consists of that part of the skin which covered

the **shoulders, neck, belly, cheeks, and face** of the animal.

Show a black-board sketch of a "crop" with dotted lines to mark how it is cut up.

Thus in a single ox-hide we have **five distinct kinds of leather,** varying in value from two shillings a pound to ninepence.

Bull-hide, bullock-hide, and cow-hide are very thick, strong, and durable. They are mostly used for **the soles of boots and shoes,** and for **harness-making.**

Calf-skin is usually employed for **the upper leather** of boots.

The hides of the animals while in the state of transition from the calf to the fully-grown ox are known as "**kips.**" When these "kips" are tanned and dressed they make a very valuable leather, almost as fine as calf-skin, but stouter and more durable.

The hide of the horse is remarkably thin, but when tanned and curried makes **a very valuable leather,** which is used chiefly by **the harness-maker. Pig-skin** is tanned into a leather **for covering saddles.**

The skins of the antelope, buffalo, porpoise, alligator, rhinoceros, and hippopotamus are amongst the hides imported for a variety of special purposes.

Our annual home-products of hides and skins of all sorts are valued at about **£7,000,000 sterling**; but in addition to this source of supply we import very largely from all parts of the world—the total value of our imports being about **£10,000,000 sterling.**

Of this amount the South American States contribute by far the largest share. India and the Straits Settlements stand next; but we also import hides from the United States, our South African and Australian colonies, and from several countries in Europe. Buenos Ayres (the great South American seaport) ships annually about **3 million hides**; Monte Video, another port almost as large, exports about **1½ million**; and Brazil furnishes about the same number.

The South American hides are the best imported, some of them weighing as much as **67 lbs.** on an average. For the purposes of exportation the hides are first soaked in strong brine for twenty-four hours, and then laid out in heaps to dry. This effectually prevents putrefaction on the voyage.

The vast grassy steppes of Russia are the home of immense numbers of horned cattle. It is estimated that upwards of **20 million hides and skins of all sorts** are produced here annually; some of these are exported, but the greater part of them are tanned and dressed by the Russians.

Lesson XLVII

LEATHER—SKINS

I. Introduction

Lead the class to describe the processes by which the hides of animals are converted into leather; the preparation of the skins by soaking and scraping; the object of this process; and the special part of the skin which is made into leather.

What is the purpose of the tanning operation? What change is effected by it? The tanned hide is actual leather, but it has to be further prepared by the currier, before it is fit for use.

Let them describe the work of currying and the cutting up of the "crop" into "butt" and "offal" leather.

II. Tawing

We have been describing the process of preparing hides—that is, heavy skins such as those of the ox, horse, buffalo, antelope, etc.—for the heavier, thicker kinds of leather.

Show a kid glove, a purse, a piece of wash-leather, or any article made of the lighter sorts of leather.

This too is leather; but it is not made from the same skins, nor is it prepared in the same way.

Goat, kid, sheep, and **lamb** skins are used for these lighter kinds of leather; but the skins are prepared, not by tanning, but by another process known as **tawing.**

For this purpose the skins, after being prepared in the usual way, are first soaked **in a solution of alum and salt,** and then in a liquor made of **wheaten flour** mixed with the **yolk of eggs.** The alum and salt by combining with the gelatine of the pelts does the work of the "bark ooze" in tanning; while the yolk of eggs and the flour give this kind of leather its peculiar softness and elasticity.

Remind the class of the way in which we prepared our rabbit-skin for last lesson.

Show the skin, and call attention to the fact that, although it is changed by the salt and alum into leather, it is still stiff. By rubbing the surface with a solution of wheaten flour and yolk of egg, we should be able to remove this stiffness, and make the skin very supple and pliant. We should then in fact have completed the process of tawing. It would be well to have a fully-prepared skin of some sort, to show the difference between the two.

The consumption of eggs is so great for this purpose that it is no uncommon thing for some of the great leather factories in Bermondsey to have at one time as many as **100,000 eggs in store,** preserved in lime or salt.

III. Uses to which Tawed Leather is put

1. **Sheep-skins.**—The skin of the sheep is sometimes tawed whole; sometimes it is split into two. The whole or unsplit skin when prepared is called "**roan.**" It resembles morocco, but is less expensive, and is largely used by bookbinders.

Sheep-skin leather is also extensively used in the manufacture of trunks and bags, pocket-books, purses,

linings for hats, boots, and shoes, cases for jewellery, musical instruments, men's braces, etc.

When split into two skins, the grain or outer one is known as a "**skiver**," the under one is called a "**flesher.**"

The "fleshers" of sheep-skins are largely used for the manufacture of **military gloves**, and for **wash-leather.** Wash-leather was formerly made from the skin of the **chamois-goat**; hence it is frequently styled **chamois** (shamoy, shammy) **leather.**

Large numbers of sheep-skins are employed as mats and rugs. For this purpose they are tawed with the wool on them, much in the same way as we prepared our rabbit-skin.

Parchment is made from the skin of the sheep, goat, and young calf. Rams' skins supply the best quality of parchment.

Vellum, a very white, fine, and smooth kind of parchment (used mostly for important documents), is prepared from the skin of the young calf.

The heavier men's gloves, known as "**dog-skin**" gloves, are made of the skin of the South African sheep.

2. **Lamb-skins** are always tawed unsplit, as they are too thin to bear splitting. From them is made a soft white leather known as **beaver,** which is used largely for making the cheaper sorts of "**white kid gloves.**"

3. **Goat-skins** are chiefly used in the manufacture of **Morocco leather.** The skins for this purpose are dressed with "shumach." This leather is used only for ornamental purposes, and is always dyed, either red or bright yellow. An inferior "Morocco" is made from sheep-skins.

4. **Kid-skins** are always used for the best kid gloves.

IV. Trade in Tawed Leather

It is estimated that our own slaughter-yards yield annually **17,000,000 sheep and lamb skins,** and our imports from other countries supply **10,000,000 more.** Our

largest shipments of these skins come from our South African colonies.

The number of goats reared in the United Kingdom is not large, but we annually import about **7,000,000 goat and kid skins,** most of which come from India and South Africa.

Woodstock has long been noted for its gloves, but the trade has declined of late years, except for military and hunting gloves. The glove-manufacture is mainly located now in London, Worcester, and Yeovil.

Limerick carries on a brisk manufacture of soft, delicate gloves—so thin and fine that it is a common thing to pack a pair of them in a walnut-shell for sale.

We import immense quantities of foreign gloves, mostly from France—the French gloves being specially sought after, both for the quality of the kid and the excellence of workmanship.

Lesson XLVIII

BONES

I. Properties of Bone

Procure a large shank or other bone from the butcher's; have it well cleaned to remove all particles of fat or flesh. Let the children take it in their hands for examination.

Refer to the earlier lessons, and lead the class to tell the properties of bone. They will at once tell that it is hard and rigid, for try as they will they cannot bend it; that it is very tough, for it will bear a great amount of rough usage without breaking; that it has a smooth surface, is dense in texture, and is consequently heavy as compared with a piece of wood the same size.

It is these properties of bone that make it suitable for its purpose in the body of the animal.

The bony skeleton or framework determines the shape

of the animal; forms a support to the body; affords protection for the delicate internal organs; and provides the means of movement.

Show a picture of the skeleton of some animal, and call upon the class to illustrate these uses by reference to mammals, birds, reptiles, and fishes.

II. Composition of Bone

Show again the bone which has been examined, and side by side with it a similar bone which has been burnt in the fire. Without telling that this one has been burnt, call one of the boys to the front, and let him strike the two with a hammer. The burnt bone at once breaks up under the blow, for it is very brittle. If the children examine it, they will find it is not at all like the other bone. It is a white substance, so extremely brittle that if they try to bend it, it will break, and they can crumble it up in their fingers.

The burning has brought about the change. This white brittle substance is all that is left from the burning. **It is earthy or mineral matter, and will not burn.** All that would burn has been consumed in the fire; only the mineral matter has been left. This mineral matter consists chiefly of **phosphate of lime.**

Show now another bone, which has been soaking for some days in dilute muriatic acid. A long rib-bone is best for this purpose.

Set some of the boys to take it out of the acid and bend it. He not only bends it readily, but he can twist it, or tie it in a knot, for all its rigidity is gone; it is very flexible and very tough. No matter how roughly he uses it, it will not break.

The acid has dissolved all the white, brittle, earthy matter out of this bone, and what is left behind is animal matter—a substance known as **ossein,** which when boiled yields **gelatine** (the very substance we found in the fibrous tissue of the skin).

If we cut a piece of it off and put it in the fire, or hold it in the flame of the spirit-lamp, it will burn. It was this

very substance—**the ossein of the bone**—that burnt away when the other bone was put into the fire.

Bone, then, is composed of animal matter—**ossein,** and mineral or earthy matter—**chiefly phosphate of lime.**

The animal or organic matter forms about one-third, the mineral matter two-thirds of the weight of bone—that is, 100 lbs. weight of bone would yield about 33 lbs. of animal matter and 67 lbs. of mineral matter.

III. Uses of Bones

Bone is one of the most important of animal products. It is largely used in the manufactures, and so great is the demand for bone that we every year import upwards of **100,000 tons,** to the value of **£700,000,** from all parts of the world.

The bones of almost all animals are useful; the bones of commerce now are chiefly those of the horse, ox, buffalo, elephant, giraffe, hippopotamus, and whale.

Lead the class to tell, as far as they can, the uses to which bone is put, the teacher stepping in when they fail.

1. **In the natural state as bone.**—It is used for knife-handles, spoons, brushes for teeth and nails, combs, fans, buttons, etc. The bones usually employed for these purposes are the shank and buttock bones of oxen.

It is estimated that in Sheffield alone no less than **two million of these shank bones** are worked up in this way every year.

The manufacture of **bone-buttons** is the source of a most extensive industry, giving employment to immense numbers of workpeople. **Birmingham** and **Sheffield** turn out bone-buttons in ton loads every year.

The first part of the manufacture is to extract all the fat from the bones. For this purpose they are boiled in enormous coppers for about 24 hours. The fat is skimmed off, and the best of it goes **to the manufacturers of butterine, fetching about £2 per cwt.** The rest, which is inferior

in quality, is sold **to the soap-makers,** and usually fetches about 30 shillings a cwt.

2. **As manure.**—*Remind the class of what happened when the bone was burnt in the fire.*

The white brittle substance left after the burning is **bone-ash,** and is much prized by the farmer as a manure for his land.

Sometimes the bones, instead of being burned, are merely crushed, and dissolved in sulphuric acid, forming a valuable manure known as **super-phosphate of lime.**

3. **As animal charcoal.**—The bones, for this purpose, are burned in closed, air-tight retorts for 12 hours, the gases being allowed to pass off as they are formed. The result of this burning is that nothing is left but **the carbon of the bone.** This is afterwards crushed into grains, and is known as **animal charcoal.**

It is employed in the sugar-refineries. The syrup of the raw sugar is filtered through this charcoal, which extracts all its brown colour, leaving it white.

The powdery dust formed by crushing the charcoal is known as **bone-black,** and is used in **the manufacture of blacking.**

Show specimens of the charcoal and the bone-black.

4. **As gelatine.**—What happened to the bone which was soaked in muriatic acid? Only the animal matter was left.

What do we call this animal matter? Ossein.

What does ossein yield when it is boiled? Gelatine.

Carry the class back to the factories where the bones are made into knife-handles, spoons, buttons, etc. The bones must be sawn, cut, and shaved in various ways to make these articles. The sawdust, shavings, and scrapings are not wasted. They are all collected up for the purpose of making gelatine.

Not only these scraps but bones themselves are used.

The bones are first soaked in dilute muriatic acid, just as we did, to dissolve out all the mineral matter. The ossein left behind is then washed and cleansed in lime-water, after which it is boiled—the boiling yielding **gelatine.**

This gelatine is poured while warm into moulds and allowed to cool. These are the jellies which are sold as a valuable article of food.

Lesson XLIX

IVORY

I. Properties

Show one or two articles made of ivory—e.g. *a knife-handle or a paper-knife. Show side by side with these similar articles made of bone.*

Let the class examine both, and try to discover some of their points of difference, the teacher assisting where necessary.

By careful comparison they will observe that the ivory is of closer grain, is much harder, and has a more highly-polished surface than the bone.

Call attention to the beautiful regular markings in the ivory. The curves may be readily seen, as they are of a slightly different shade of colour from the rest of the substance.

Notice how the curves cross each other, something like the markings on the back of an engine-turned watch-case.

No specimens of bone—indeed, no other animal substance of any kind has these peculiar markings. Hence this is **a sure test for distinguishing ivory from bone.**

II. Sources of Supply

Lead the children to tell what they can of the structure of their own teeth.

The body of the tooth consists of **dentine**—a substance somewhat resembling bone. This is covered with a hard, white, smooth substance, called **enamel.**

The ivory of commerce is furnished by the teeth and tusks of various animals, especially the elephant, hippopotamus, and walrus.

We have had frequent investigations into the teeth of animals, and have found certain teeth specially developing themselves, according to the wants of the individual animal.

Which teeth are most highly developed in the flesh-eaters? Why? Think of the rabbit and the rat. Which teeth are most important in these animals? Why?

Where would you find the most important teeth in the horse and the ox—grazing animals? Why?

1. **Elephant - ivory.**—The elephant is a grazing animal, and has large molar teeth. He has no canine teeth, and **the two incisors** in the upper jaw grow to an enormous size, **forming tusks** which project beyond the mouth. There are **no incisors** of any kind **in the lower jaw.**

The tusks of the elephant are the largest teeth to be met with in the animal kingdom; they grow to their enormous size because of the absence of any teeth in the lower jaw to oppose them.

The elephant uses his tusks in uprooting trees to get at the young herbage growing on the upper branches. They also form very formidable weapons of attack and defence.

The African elephant is a much larger animal than the elephant of Asia, and his tusks attain immense proportions. A single tusk will sometimes weigh from **150 to 175 lbs.,** and measure **10 feet in length.** The female as well as the male is furnished with tusks.

Those of the Indian elephant usually weigh from **60 to 80 lbs.** The elephants of Ceylon and Siam furnish very beautiful and highly-prized ivory, but the tusk does not weigh more than **25 to 30 lbs.**

The best, hardest, whitest, and closest-grained ivory is obtained from near the pointed ends of the tusk—the base of the tusk is somewhat hollow and spongy.

Wild elephants live together in vast herds, and are hunted and killed for the sake of their ivory tusks. It is estimated that quite **20,000 elephants** are slaughtered annually to supply the ivory which is imported into the United Kingdom alone.

The quality, and consequently the value, of ivory varies considerably. The largest tusks are the most valued, as they can be worked to greater advantage. Tusks that weigh a hundredweight or upwards are classed first in value, and fetch as much as **£50** or **£60 per cwt.** Smaller tusks weighing from 35 to 50 lbs. are worth about **£40 per cwt.** The smallest tusks below 18 lbs. in weight are known as "**scrivelloes.**" They are mostly used for cutting billiard-balls.

2. **Fossil - ivory.**—*Show a picture of the mammoth. Explain that this huge hairy elephant is now extinct; but that vast quantities of mammoth tusks are every year dug out of the frozen soil in northern Siberia and Alaska, thus proving that the animals once abounded in those regions.*

For hundreds of years this fossil-ivory has formed an important article of commerce. It is estimated that about **20,000 lbs.** of it finds its way into the Russian markets every year. As many as ten fossil tusks have been dug out in one spot, many of them weighing between **150 and 300 lbs. each.**

In spite of these enormous quantities of fossil-ivory removed every year, the store does not seem to materially diminish, for in many places the tusks are found lying about in heaps.

The Russians make great use of these fossil-tusks; but as the ivory is inferior in quality it is not much esteemed in England.

3. **Hippopotamus-ivory.**—*Show a picture of the hippopotamus. Call special attention to the two tusks.*

These are the **canine teeth,** and **not incisors;** but they never grow beyond a certain length in this animal, because the bottom incisors are present, and to some extent oppose them.

Hippopotamus-ivory is very highly esteemed, as it is harder and whiter than elephant-ivory. It keeps its colour too better than some kinds, which are apt to turn yellow.

This ivory was very much in demand till late years by

dentists for the manufacture of false teeth, and fetched as much as thirty shillings a pound. It is not used for this purpose now; it has been replaced by other substances.

4. **Walrus-ivory.**—*Show a picture of the walrus. Tell briefly the nature and habitat of the animal. Call attention to the long tusks of the upper jaw. Compare them with the tusks of the elephant.*

They are **the canine teeth** largely developed, and form the creature's weapons of attack and defence; it uses them also to assist its landing on the slippery ice. The ivory is of less value than that of either the hippopotamus or the elephant.

III. Uses

The readiness with which ivory can be cut, carved, and turned; the beauty of its hard polished surface; and its great durability make it specially suitable for many purposes in the arts, both useful and ornamental.

It is chiefly employed for making knife-handles, paper-knives, backs for brushes, combs, pianoforte and organ keys, billiard-balls, and a large variety of fancy and ornamental articles. Cut into thin plates it is used in bookbinding as covers for books, and also for writing-tablets.

Lesson L

HORNS

I. Kinds of Horns

Lead the class to think for a moment about the ox and the horse. What is perhaps the most striking difference in the appearance of the two animals? The ox has horns, the horse has not. **Horns** *will form the subject of our lesson.*

Call upon the children to name as many animals as they can which have horns. When they have exhausted their list, which

will probably end with the ox, ram, goat, deer, and antelope, show them that all these are ruminating animals or cud-chewers. Indeed nearly all the horned animals chew the cud.

Show a bullock's horn, and side by side with it (if possible) a stag's antlers. If the antlers cannot be obtained, show a picture.

Both these are horns; but there is a great difference between them—there is considerable difference even in appearance.

Let the children examine them one by one.

The bullock's horn is hollow, curved, broad at the base and tapering to a point; it is very hard, tough, and elastic, and smooth and shiny in appearance.

Explain that although the horn we are examining is hollow, it was not hollow on the animal's head.

It was really a hard, strong, protecting covering for **a bony core** which grew out from the frontal bone of the skull

This bony core, which is really part of the skull-bone itself, projects from the head, and the horn covers it like a sheath, for it is very tender and sensitive.

The horny material of which this covering-sheath is made is the same kind of substance as that which forms **the claws of mammals, the talons and beaks of birds, and our own finger-nails.**

Oxen, sheep, goats, and antelopes have these **hollow horny horns.** Some of the antelopes have straight horns, but in all the other members of the group the horns are more or less curved like those of the ox, and some are twisted.

These hollow horns make their appearance early in the life of the animal, and **continue to grow as long as it lives.** They vary in size, in some cases measuring six feet from tip to tip.

Certain antelopes of America **shed their horns** periodically; but none of the other animals do so, and hence, with this exception, we may describe them as **permanent horns.**

The rhinoceros has the same kind of horny horn, but it is solid, and not hollow like those we have been examining, and there is no inner core.

Call attention next to the horns of the deer.

These are altogether different from the hollow horny horns. They consist of a number of spreading branches, and are usually called **antlers** in preference to horns.

Show pictures of the stag and the reindeer. Call attention to the difference in the development of the antlers. In the one animal the antlers branch out **like the branches of a tree,** *in the other the branches* **are flattened out.**

These antlers are hard, solid bone, and not horny matter. They are parts of the frontal bone of the skull grown out, but without any outer covering-sheath of horny matter.

Antlers of this kind are common to all the deer family, but, with the exception of the reindeer, **only the males have antlers.**

In every case the antlers are shed each year, and new ones take their place. Hence these are sometimes called **deciduous horns.**

Each new pair are more fully developed than their predecessors as the animal advances to maturity. In the fully-grown deer the antlers become very large and wide-spreading.

II. Properties of Horn

Take a piece of cow-horn; break it up to show that it consists of closely compressed fibres, and is **very tough and elastic.**

Hold a piece in the flame of the spirit-lamp. **It burns** *with a frizzling noise, a slight flame, and an unpleasant odour.*

Put a piece in some boiling water. After a time it begins to soften, and if soaked long enough, it would become so **soft** *and* **plastic** *that it could be readily cut, moulded into various forms, and even* **welded together.**

The bony matter of the antlers of the deer has none of these properties. It is actual bone, resembling in almost every particular the ordinary bone in the body.

III. Uses of Horn

The horns of animals are extensively used in manufactures. The antlers of the deer family are mainly employed in making handles for carving knives and forks, pocket-knives, and a variety of ornamental articles.

The horny horns, and especially those of the ox, are used for making combs, drinking-vessels, shoe-lifts, knife-handles, buttons, umbrella-tops, etc.

Buttons are usually made from the solid tips of the horns. They are first softened in boiling water, and then pressed into the required shape.

Rams' horns are sometimes made into snuff-boxes in Scotland.

IV. Trade in Horns

Our annual imports of horns of all kinds average about **5000 tons,** valued at **£160,000.**

Most of our supplies come from India, South Africa, the East Indies, the United States, South America, and Australia.

British India and **the Straits Settlements** alone send us on an average **2500 tons of horns,** mostly those of the ox and buffalo, and this is estimated to represent the slaughter of no less than two million head of these cattle annually.

Nearly one-fifth of our total imports of ox and buffalo horns are used in the manufacture of combs; the annual value of horn combs manufactured in this country is said to reach **£400,000.**

The cutlery-works of Sheffield use up annually for knife-handles, etc., about **400 tons of foreign stag-horns,** besides **100 tons** from Europe and our own deer-forests.

Lesson LI

TALLOW AND OFFAL OF ANIMALS

I. TALLOW

THE fat or tallow of animals, especially of those whose flesh is used as food, forms an important article of commerce. It is obtained by boiling down the carcases in huge boilers; the fat, of course, floats on the top, and is drawn off into coolers.

Tallow is used now mostly in **the manufacture of soap.** Formerly large quantities were made into candles; but since the introduction of solid paraffin very few tallow candles have been made.

Lead the class to tell all they can of the principles of the soap manufacture, the teacher assisting where necessary.

Our home-product of tallow amounts to about **120,000 tons annually,** but we import, in addition to this, from two to three million pounds' worth.

Most of our imported tallow comes now from South America, the United States, Australia, and Russia. Russia formerly supplied by far the largest quantities, but of late years the trade in Russian tallow has declined.

Till recent years Australia reared its sheep and cattle almost solely for the sake of the wool and hides, there being little demand for the flesh.

Whole carcases were boiled 300 or 400 at a time in huge vats or boilers, eleven or twelve feet high. The fat was drawn off for tallow; the flesh was used for feeding pigs, or put on the land as manure.

In New South Wales and Victoria the number of carcases of sheep alone boiled down annually in this way for tallow averaged **one and a half million.**

The rise of the Australian trade in frozen carcases as

food for the home-market has now caused a corresponding fall in the supply of tallow from these colonies.

II. Offal

Under the head of offal are included all the waste or refuse parts of the carcase, as well as certain parts which are used as food—*e.g.* the head, tongue, feet, heart, liver, kidneys, lungs, tripe, gut, and bladder.

1. **Offal used as food.**—The tripe-dressers of London and other large towns carry on an extensive and flourishing trade in the preparation and sale of offal as food.

Some parts of it are highly esteemed as delicacies; others form cheap and wholesome food for the poor.

Calves' heads form a nutritious dish which is regarded as a luxury. Ox-tongues are also largely in demand as a delicacy. We import immense quantities of salted tongues from South America, Russia, and Australia.

The feet of oxen, when boiled, yield gelatine—a very wholesome food. Calves'-foot jelly is much esteemed as a delicacy for invalids.

There is a large amount of fatty oil in the foot of the older animal, which has to be extracted before it is fit for food.

The fat extracted is the useful oil known as **neat's-foot oil.**

2. **Offal used for other purposes.**—The accumulation of animal refuse in the slaughter-houses and meat-markets of our large towns was formerly a source of great danger to the community, and various means were adopted to destroy it, or get rid of it in some way before it could work mischief.

Now every part of it is applied to some definite purpose, and provides a remunerative source of employment and profit.

(*a*) **The blood** of the slaughter-houses, instead of being allowed to run away into a drain as useless, is now put to various uses, either as food or in the industrial arts.

The blood of pigs and sheep is used for making black puddings, and in Sweden the lower classes of the population live on **a very wholesome bread** made of the blood from the slaughter-houses mixed with wheaten flour.

Blood is largely used in the arts in the form of blood-albumen.

Call upon the class to tell the nature of albumen, and its familiar form as "white of egg." It is the most important constituent of blood.

One kind of blood-albumen is obtained from the clot after the blood is allowed to stand for some time; another kind is derived from the "serum" or liquid part of the blood.

The first of these is used by **calico-printers** to produce the colour of the particular kind of cotton-cloth known as **Turkey-red.** It is estimated that upwards of **6000 tons of blood** are used annually for this purpose. That derived from the blood-serum is employed by dyers as a mordant for fixing or "biting in" the colours in woollen fabrics.

Dried blood is used to clarify wines and syrups, and it also forms a valuable manure for the land.

(*b*) **The intestines** of animals are prepared for various purposes, and are thus the source of large and important branches of manufacture.

The delicate membrane of the small intestine of the ox is the material from which goldbeater's skin is made. One London maker alone of this article is said to work up the gut of no fewer than **10,000 oxen every week.**

Other parts of the gut are made into strings for musical instruments, lashes, and whip-cords, and skins for sausages and polonies.

(*c*) **Cow-hair** is used for mixing with mortar for plastering purposes, but not so much as formerly, because it can now find (at least the best of it) a better market.

Large quantities of it are now made up into **cheap imitations of sealskin** for ladies' jackets, etc. The best of the hair for this purpose realises from **£10 to £11 per ton.**

The coarser, rougher hair is used for making felt for roofing purposes, stuffing chairs and sofas, etc. It is also made into ropes, as well as carpets and other textile fabrics.

(*d*) **Glue, gelatine, and size.**—*Show a piece of glue. Call upon the class to tell its uses, and the way in which the joiner and cabinet-maker prepare it as a cement.*

Glue is made from all sorts of refuse animal matter, including the fleshings (*i.e.* the parings of the hides from the slaughter-houses and tanneries), the refuse parts of the hoofs and ears of horses, oxen, and sheep, and the cuttings and scrapings of the horns of animals.

Almost any animal offal and garbage, useless for other purposes, is available as a material for making glue.

The dried sinews, the inner bony core of the horns, even old worn-out leather (if it is first deprived of its tannin)—all are made to yield glue.

Size is a weak solution of glue allowed to cool and clarify. Scraps of vellum and parchment, old kid gloves, and rabbit-skins are used as materials for making gelatine and size.

The process of glue-manufacture is simple. The fleshings are cleansed by being soaked in lime-water and washed; after which they are boiled. The impurities rise to the surface and are skimmed off during the boiling, and the clear liquid is then run away into moulds and left to dry and harden.

The prices of glue in this country vary, according to the quality, from **£45** to **£75 per ton.** It is estimated that the average quantity of glue used is upwards of **10,000 tons.**

Gelatine is used for **stiffening straw hats** and for **dressing silks** and **other fabrics.** It is also used as an **article of food.**

That used for food is usually made from sheep's feet, old worn-out parchment, and the waste cuttings of glue. Size is chiefly used for mixing with whiting and colour in white-washing and colouring ceilings and walls.

Lesson LII

FUR

I. Introduction

Show some specimens of fur. Lead the class to name other kinds, the teacher adding to the list where necessary. Refer to the earlier lesson on the coverings of animals, and elicit from the class the chief properties of fur.

Lead them to tell, from these properties, the peculiar adaptability of this kind of covering to the climate and conditions under which the creatures live.

Call attention to the animals named in the list, and show that in almost every instance they belong to the frozen north, where their thick coats of non-conducting, non-radiating fur protect them from the rigour and inclemency of the climate.

Notice too that the vast majority of them are wild animals, which are hunted and trapped in the wildest regions of the earth, remote from the haunts of man. An examination of the list will show that these fur animals belong to either **the Carnivora** *or* **the Rodentia**—*the greater part of them being flesh-eaters.*

II. Trapping and hunting the Fur Animals

Siberia and British North America are the two great fur-producing regions of the world. They form immense hunting-grounds for almost every variety of fur-bearing animals. They give constant employment to large numbers of adventurous men, who in their trapping and hunting are exposed to great risks and dangers.

The Siberian trappers are usually hardy men from the poorer classes.

In North America, although many hundreds of white men are employed as fur-hunters, the hunting and trapping are mostly in the hands of the Indians, who barter the

skins they obtain for blankets, biscuits, and a variety of articles of use and personal adornment.

Siberia supplies by far the largest part of the fur-trade of the world. Among its fur animals are the sable, marten, beaver, fox, squirrel, ermine, wolf, bear, lynx, badger, sea-otter, and seal.

Pictures should be shown of as many of these animals as possible, and the nature and habits of each should be briefly told.

The richest and handsomest furs are obtained from the eastern part of Siberia.

It is said that China alone imports annually from Siberia from **two to three million squirrel-skins,** to say nothing of other furs. Turkey and Persia are also large importers of Siberian furs.

Winter is the fur-hunting season. Why?

All through the winter the trappers are busily engaged collecting the furs in the wildest and most solitary parts of the country. After the break up of winter they bring their collections to certain towns, where annual fairs are held for the sale of the furs and other commodities.

Among the most important of these towns are Nishni Novgorod on the Volga, Archangel on the White Sea, and Yakoutsk on the Lena in eastern Siberia; each of which acts as a central depôt for the fur-trade in its own part of the empire.

The Emperor of Russia derives part of his private income from a tribute which is paid by certain Siberian tribes in the form of the most costly furs.

The fur-trade of North America was till 1860 entirely in the hands of the Hudson Bay Company; but since that time it has been taken up by numbers of other traders.

Victoria in Vancouver Island is the chief depôt for the Hudson Bay traders, who confine their operations mostly to the North-West Provinces, Hudson Bay, and the Rocky Mountains.

New York, Boston, and St. Louis in the United States, and Montreal in Canada are the chief centres of the fur-trade for the eastern part of the continent.

The principal fur-bearing animals of America are the sea-otter, common otter, seal, black, red, white, and silver foxes, the panther, wolf, beaver, racoon, black and brown bears, the wolverine, badger, musk-rat, lynx, ermine, and marten.

The furs sent out annually from British Columbia form the most important and valuable of its exports.

The estimated total collection of furs from all the fur-producing countries of the world in a single season does not fall far short of **30 millions**—the total value being upwards of **£3,000,000 sterling.**

III. The Fur-Trade

Remind the class of the rabbit-skin which we dressed with salt and alum for one of the former lessons.

Lead them to tell that the skin thus dressed would resist putrefaction, and the fur itself would not fall out.

What general name do we give to these fur-skins? We call them **pelts.**

The pelts, as they are taken by the trappers, are simply rubbed and salted to arrest putrefaction, and are brought in to the depôt in that state.

At the depôt they are cleansed and cured, and then packed in large casks for shipment to England and other countries, where they command high prices, and yield large profits to the traders.

The value of the fur depends upon the quality and also on the condition of the skin. If the pelt is torn through the struggles of the animal in the trap, or riddled with shot, or badly stretched and dried, it loses materially in value.

On the other hand, it is a remarkable thing that so little of even a spoilt pelt is really wasted. The smallest clippings, cuttings, and remnants are pieced together with marvellous skill, so that it is often difficult to see that it is not a whole skin.

Immense shipments of furs find their way every year to London, which is a great centre of the fur-trade.

The work of the furrier is to dress and beautify the skins.

Let the class tell the nature of **the over-hair,** *and the part it performs for the living animal in keeping the fur from matting or felting together.*

Many skins owe their elegance and value to the length and fineness of this over-hair; but in the preparation of the seal-fur the over-hair is all cut away.

Show a sketch of the fur with its over-hair. Call attention to the long, coarse hairs, whose roots are more deeply embedded in the skin than the fine delicate hairs of the under-fur.

The over-hair of the sealskin is removed in a curious way. The skin is stretched out flat with the flesh side uppermost, and part of the skin is pared or shaved off with a sharp flat knife. In cutting away this under surface of the skin, the deeply embedded roots of the over-hairs are cut through, and it is an easy matter then to pull out the hairs.

Show an ordinary felt hat, and lead the class to tell its history.

The furs we have been considering are the costly fancy furs; but many millions of rabbit, hare, musk-rat, cat, and coypus kins are used for making felt. The fur alone is used for this purpose. It is removed from the skin, and beaten and pressed until it becomes matted or felted together.

This branch alone of the fur-trade forms a thriving industry, not only in England, but also in France, Belgium, and Germany.

Lesson LIII

THE WHALE AND ITS PRODUCTS

I. WHALEBONE

INTRODUCE by showing a piece of whalebone. Call upon the class to tell what it is, and to mention some of the purposes for which it is used.

We call this substance whalebone, but **it is not really bone,** and it is not obtained from the actual bones of the whale. Let us examine it, and find out all we can of its properties, and what it really is.

Hand the specimen round the class for inspection. Lead the children, as a result of their examination, to tell that it is a **fibrous substance,** *because they can pull it to pieces in shreds or fibres; that it is* **tough and flexible,** *and has a close resemblance to horn; that it is very* **elastic,** *because if they bend it, it springs back to its former shape as soon as it is let go; that it is very* **light,** *for it* **floats in water.** *In fact, it is not at all like bone.*

1. **What it is.**—This substance, whalebone, is found in the mouths of certain kinds of whales. Its proper name is **baleen.** These whales have no teeth; but they have, hanging down from the upper jaw, on each side of the tongue, an extensive row of **about 300 flat plates or blades of baleen.**

These baleen plates are at right angles to the jaw-bone, and hang parallel to each other. They form, as they hang from the roof of the mouth, a transverse arch; the inner edge of each plate being **fringed with stiff but flexible hairs.** When the mouth is shut, the fringed edges of the baleen plates rest on the upper convex surface of the tongue.

The largest of the baleen plates spring from the middle or highest part of the roof. These are sometimes from 12

to 15 feet in length. Each plate is usually from 10 to 12 inches wide at the root, and about ½ inch thick. The plates diminish in size as they near the front of the mouth, those in the front being only a few inches long.

The lower jaw has no baleen plates.

Draw a black-board sketch of the skull of the whale, showing the baleen plates.

One of the largest plates usually weighs 7 lbs., and the total yield of whalebone from a large whale is about 1 ton. It is only in certain kinds of whales that these baleen plates are found. They are—

(*a*) **The Greenland whale** of the North Polar Seas, particularly Davis Strait and Baffin's Bay.

(*b*) **The South Sea** or **black whale** of the great Southern Ocean, especially round the Australian coasts and the southern extremities of Africa and America.

(*c*) **The Pacific** or **American whale** of the north coast of America, the great fishing-ground being the neighbourhood of Behring's Strait.

These whales are all very different in shape and size, the largest and most valuable being the Greenland whale.

Show a picture of the Greenland whale.

This enormous creature, the largest of all animals in the world, sometimes reaches 80 feet in length.

It will interest the class to tell them that it would be quite possible for 40 *or* 50 *of them to stand comfortably inside the whale's mouth.*

Picture to them the immense mouth, and its vaulted, cavernous roof, with the rows of fringed baleen plates hanging down from it. If the teacher himself stood on the whale's tongue, he would not be able to reach the roof with his upstretched arms.

2. **Uses of the baleen plates and fringes.**—The baleen whales are all alike in having no teeth. Hence, in spite of their enormous size, they are unable to kill and devour other large inhabitants of the sea. Their food, in fact, consists of **very small animals**, for the most part of **small soft-bodied animals** which exist in myriads in **every sea.**

Rouse the curiosity of the class by comparing the massive creature itself with the animals on which it feeds. What an enormous number of such small things it must take to supply one meal. How can it catch sufficient?

Tell of the wide-open, cavern-like mouth, and the rapid speed at which this powerful creature forces its way through the water.

The mouth, with its fringed baleen plates, is a trap to catch hundreds and thousands of the small prey as the animal rushes through the water.

3. Uses to which we put whalebone.—Whalebone was till late years largely used for the ribs or stretchers of umbrellas. Nowadays steel frames are mostly used, but whalebone is still employed for the best carriage umbrellas. It is also much used, split into fibres, as a **substitute for bristles** in coarse brooms and brushes. It is used in thin narrow slips to strengthen women's stays and corsets. Whalebone softens when heated, **and becomes plastic.** In this state it is moulded into a variety of articles, such as **knobs for walking-sticks, whip-handles,** etc.

The plasticity of whalebone may be shown by heating a piece of the substance over the spirit-lamp in a large spoon filled with sand. When the sand has become quite hot, remove the softened whalebone, and let the children bend and mould it at their pleasure.

II. Whale-Oil

Refer to the earlier lessons, and lead the class to tell that the whale, although it has its home in the sea, is a **mammal**; *that it has* **warm blood**; *that it has* **lungs** *like all other mammals; and that it* **cannot breathe under water.**

This warm-blooded mammal lives in the icy seas. What is nature's provision to prevent the bodily heat from passing away too rapidly? Not a thick covering of wool or fur; why?

The whale's body is enveloped in a coat of fat immediately under the skin, varying from 8 to 20 inches in

thickness. This fat is known as **blubber**, and acts as the whale's under vest to keep him warm.

When a whale is caught the blubber is all removed from the carcase for the sake of the oil it contains. The blubber of a full-grown whale will yield **100 tuns of oil.**

III. Spermaceti

The sperm whale or **cachalot** of the Eastern Archipelago (that is the seas between Australia and Japan) is a very different animal from the baleen whale. It is sought after for the sake of a very valuable oil—**spermaceti**—which is obtained from the head.

Show a picture of the sperm whale.

It has an **enormous head, formidable teeth,** but **no baleens.** The head of a full-grown sperm whale is said to weigh about 35 tons, and will yield 45 barrels of **spermaceti oil.**

The oily matter of the head is contained in a triangular-shaped hollow, which is known as the "**sperm case.**" To obtain the oil the whalers make an opening in the "sperm case," and dip out the contents with buckets. It is carefully boiled, and when purified separates into a kind of wax-like substance—the **spermaceti** of commerce —and oil.

Spermaceti is used mostly for making candles, but its use for this and other purposes has greatly diminished during the last quarter of a century.

The introduction of petroleum and vegetable oils has had the effect of driving this and most other animal oils out of the market.

The consequence is that the whale-fisheries have gradually declined, both as regards British and foreign ports, while France has given them up entirely.

Peterhead and Dundee in Scotland are now the only British ports which send out whalers.

Our imports of whale-products now average about **100**

tons of whalebone, worth from £50 to £150 per ton; about **2000 tuns** of oil, valued at £28 to £32 per tun; and about **4000 tuns** of spermaceti, worth from £90 to £100 per tun.

Some of our colonies in the southern hemisphere, *e.g.* New Zealand and Tasmania, are engaged in the whale-fisheries round their coasts, and are able to export after supplying their own requirements.

IV. Mode of capturing the Whale

Time should, if possible, be found to give a graphic description of the whale-fishery.

Tell of the ships setting out, fitted for a long voyage, but bound to no port, provided with apparatus for draining the blubber and boiling the oil, and stowed with barrels to receive it when it has been boiled.

They cruise about till a whale is sighted. Tell of the blow-hole, the habit of spouting, and what it means. The boats are lowered and follow up after the whale. Tell of the harpooner.

Show a picture of a harpoon.

When within striking distance, the harpooner hurls the weapon into the monster.

Tell of the instant darting off, the rapid rush downwards through the water. The harpoon is attached to a strong flexible cord which is coiled round carefully in a tub or barrel, and pays out as the creature descends.

Whale bound to come up again. Why? It no sooner appears on the surface than it receives another harpoon, and so on.

At last worn out with its struggles and loss of blood, it turns over on its side and dies. It is then towed by the boats to the ship and made fast to the ship's side.

Describe now the men standing on the floating carcase cutting out huge pieces of the blubber with their sharp spades.

A sharp hook attached by a chain to a crane over the ship's side is fastened into each piece as it is cut, and the piece is literally torn away as the crane is set in motion.

Lesson LIV

SILK

I. Properties

Show a piece of silk. Let the children examine it. Lead them to tell that, although it is very thin and light in texture, it does not readily tear—**it is very strong**; *that it is soft and pliable, and that its chief beauty lies in its* **rich lustre.**

Instruct them to unravel the material. Let them tell that the substance itself consists of woven yarn or threads. Untwist the individual threads and show the fine flossy fibres of which they are composed.

II. Source of Supply

Remind the class of the lesson on the spider. Lead them to tell that the spider spins a web to serve as a trap to catch its prey; that the material of the web is, when it leaves the spider's body, a sort of gum; that this gum dries on exposure to the air, forming a fine silky thread.

Lead them next to think of the life-history of an insect. Let them describe the changes from **grub** *to* **pupa,** *from* **pupa** *to* **perfect insect.**

Many grubs, when about to enter the pupa or chrysalis stage, envelop themselves in a kind of silky covering, which they spin with material from their own bodies. The destructive rose-maggot may always be met with in the spring curled up in a leaf of the tree in a loose flossy covering of its own spinning.

Most caterpillars prepare for the chrysalis stage in the same way, but the silk which they spin is useless.

One special caterpillar, known as the **silkworm,** supplies all the silk of commerce.

III. Natural History of the Silkworm

Show (if the season permit and it be otherwise possible) some silkworm-moths, some eggs, and some silkworms.

The moth is **the parent insect.** It lays from 250 to 400 eggs, smaller than grains of mustard-seed.

Where does the butterfly lay its eggs? On the leaves of the plants in the garden.

Why? The leaves form **the natural food** of the caterpillars which come from the eggs.

The favourite food of the silkworm is the **leaf of the mulberry tree.** People, therefore, who rear silkworms provide a constant supply of fresh mulberry leaves, and the mother-moth lays her eggs on the leaves.

The grub, when hatched, leaves the egg in the form of **a little black worm,** not more than $\frac{1}{4}$ inch in length, but there is plenty of food at hand, and it feeds and grows quickly. As it grows **it casts its skin** when it becomes too small—another skin taking its place.

During its growth the silkworm **moults,** or **casts its skin, four times.** The first moult takes place about eight days after it leaves the egg; the second, third, and fourth at regular intervals of about five days each.

After the last moult it feeds voraciously on the mulberry leaves and continues to grow for about ten days, when it may be said to have reached its full size, and is then nearly two inches long. It now ceases to feed, and after fixing itself to some light object, such as a twig, a bit of straw, or a bit of paper rolled up, it commences to send out, **from two small holes under its jaw,** a fine yellow gum-like substance, which hardens into a silky thread or fibre on exposure to the air. With this the creature completely envelops itself as in a ball.

The first day is usually spent in forming **a loose flossy covering for the outside** of the ball. This is afterwards coated with gum, so as to make it into a kind of outer skin.

Inside this, during the next three days, the silkworm spins a firm ball of fine but strong yellow fibre, which is the silk of commerce.

The whole forms an oval ball about the size of a walnut, and is called a **cocoon.**

Show a cocoon. Explain that, when the spinning is completed, the animal—whatever it is—is in the centre. It is not a silkworm, it is not a moth. It is a lumpy, oval ball, covered with a shiny skin or shell, but to all appearance lifeless. It is the **silkworm chrysalis.**

Open one of the cocoons and show the chrysalis within.

After about ten days the chrysalis would, if left to itself, give ample proof that it is not lifeless. During its imprisonment in the cocoon it undergoes wonderful changes, and at the end of the time emerges from the ball, not as a grub, not as a chrysalis, but as **a winged moth** able to fly in the air.

After living long enough in the new stage to lay the eggs of a future race of silkworms, the moth dies.

IV. Unwinding the Cocoons

In order to obtain the silk from the cocoons, the worm inside must be killed before it reaches maturity as a moth. This is usually done either by throwing the cocoons into boiling water or by putting them into a hot oven for a few minutes. The hot water softens the gum on the cocoon, so that the loose outer skin is easily pushed aside to allow the inner ball of fine silky fibre to be taken out.

Impress upon the class the delicate nature of the silky threads of the cocoon. Lead them to see that the process of unwinding the silk without breaking the thread must be performed with great care.

Remind them that as the silkworm commenced its spinning operations from the outside, the first step in the unwinding is to find the outer end of the thread.

With care the rest is easy. The thread is unwound by

means of a rotating reel. From the reel the silk is made up into bundles or hanks, and is known as **raw silk.**

A single cocoon usually yields from 300 to 500 yards of silk, but in some cases the yield is greater. It is estimated that 250 cocoons weigh 1 lb., and as it takes 12 lbs. of these cocoons to produce 1 lb. of silk, it therefore follows that 1 lb. of raw silk is the result of the work of 3000 silkworms.

V. The Silkworm at Home

The silkworm will not thrive in our cold latitudes. The principal silk-producing countries of the world are China, Japan, India, Persia, Turkey, Italy, and the South of France. Of these, China provides by far the greatest supply—more than all the rest put together.

We import annually from **4,000,000** to **5,000,000 lbs.** of raw silk for our home manufactures, but our main supply of silk comes to us in the form of manufactured goods mostly from France.

VI. The Silk Manufacture

The silk manufacture is not one of our great manufacturing industries. Yet we have important centres of activity in the various branches of the trade.

Silks, satins, brocades, and velvets are made in Spitalfields (in the east of London), Macclesfield, Glasgow, Paisley, Manchester, and Dublin.

Stockings and gloves at Nottingham.

Crape at Norwich and Colchester.

Ribbons at Coventry, Macclesfield, and Derby.

OBJECTS AND OTHER ILLUSTRATIONS REQUIRED

STANDARD V

Lesson I

A brick; two bottles; some water, treacle, tar, paraffin, salt, loaf-sugar, gun-cotton, chalk, olive-oil, mercury; test-tube; Bunsen burner.

Lesson II

Two or three tumblers; some water; hammer; nails; a piece of wood; some litmus or cochineal; air-tight stoppered bottle; air-pump; a piece of thick malacca cane; some mercury; salt; a sponge; a piece of new bread; cork; wool; cane; whalebone; a watch-spring; india-rubber; flannel; small air-balloon; a glass marble.

Lesson III

A two-foot rule; a tape-measure; compasses; callipers; some inch cubes of wood or stone.

Lesson IV

A thin bar of copper and another of iron riveted together, end to end; the Bunsen burner; some phosphorus; a thin strip of copper; a piece of bone; the evaporating dish; pieces of cork, marble, stone, brick, wood, leather, wool; some ice; hot water.

Lesson V

A large test-tube; some ice; a piece of wire; the test-tube holder; the spirit-lamp; a large glass flask; some blue litmus; Bunsen burner.

Lesson VI

A glass flask; the Bunsen burner; a small thermometer; a sponge; spirits of wine; salt; a retort fitted into the neck of a flask; some ice; black-board sketch of a still.

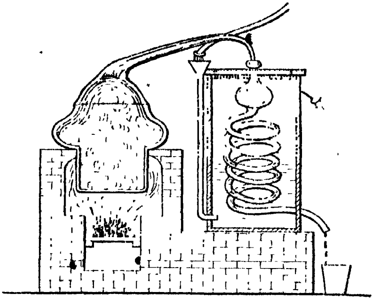


Fig. 1.

Lesson VII

A test-tube corked; the Bunsen burner; a black-board sketch showing a simple section of a steam-engine.

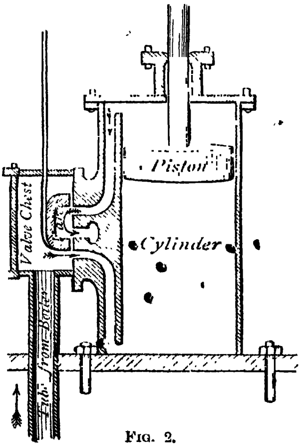


Fig. 2.

LESSON VIII

An iron ball and chain ; a ball of wool thickly studded with pins ; two meat-tins, one coated with lampblack on the outside ; two thermometers.

LESSON IX

A tumbler of cold water.

LESSON X

The large partitioned bottle and taper, as described in the lesson.

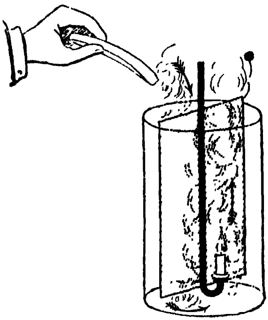


FIG. 3.

LESSON XI

The terrestrial globe.

LESSON XII

Two balls—one of iron, the other of lead ; some boiling water ; some cold water ; mercury ; two small thermometers ; two or three test-tubes.

LESSON XIII

A hen's egg ; a cup ; a bone which has been standing in dilute muriatic acid.

Lesson XIV

An egg and a cup, as in Lesson XIII.; some milk, cream, sugar; an iron spoon; a bone that has been burned in a bright red fire.

Lesson XV

The objects used in the last two lessons.

Lesson XVI

A few ears of wheat, oats, barley; a "cob" of maize; some grains of rice; some wheaten flour, oatmeal, barley-meal, maize and rice flour, sago, arrowroot, and tapioca; pictures of each of the growing plants; a basin of water.

Lesson XVII

Some peas; some Windsor, French, and haricot beans, and lentils.

Lesson XIX

Specimens of fur, leather, silk, linen, cotton; pictures of the flax and cotton plants; a thermometer.

Lesson XX

Two large bowls; some rain-water and some hard water; soda; specimens of washing powders.

Lesson XXII

Specimens of tea; a cup; some boiling water; some specimens of serrated leaves; a picture of the tea-plant.

Lesson XXIII

Some ground coffee; some coffee-berries (raw and roasted); a cup; some boiling water; a small coffee-mill; a picture of the coffee-tree.

Lesson XXIV

Samples of different preparations of cocoa and chocolate; a picture of the cocoa-tree; a poppy-head; some cocoa-beans; a cup; some boiling water.

Lesson XXV

The spirit-lamp; some almonds; a sheet of blotting-paper; olive-oil; oil of peppermint; linseed; linseed-oil; colza-oil; castor-oil; palm and cocoa-nut oil; a cocoa-nut with the outer husk; pictures of the oil-palm and cocoa-nut palm and the olive-tree.

Lesson XXVI

Specimens of camphor, gum-arabic, and British gum; the spirit-lamp; the evaporating dish; some water; alcohol; one or two tumblers; bottle of gum.

Lesson XXVII

Piece of resin; some oil of turpentine; some coal-tar, Stock-

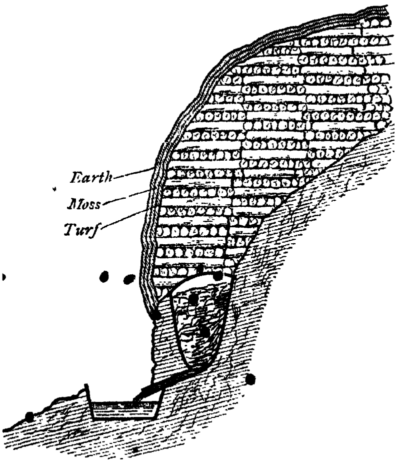


Fig. 4.

holm tar, and pitch ; a black-board sketch showing the mode of obtaining tar from the roots of the pine-tree ; a tumbler ; the spirit-lamp ; some water ; spirits of wine ; picture of a pine-tree.

Lesson XXVIII

Pieces of calico, cotton-print, dimity, muslin, lace, fustian, corduroy, velveteen ; a cotton-pod ; a picture of the cotton-plant ; some cotton-seed ; a large piece of calico showing

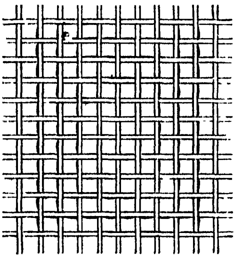


Fig. 5.

the selvage ; a picture of the hand-loom ; black-board sketches (1) showing the arrangement of the warp and woof, (2) the shuttle.

Lesson XXIX

A skull of some animal, and a few of the vertebral bones should be provided ; a good wall-sheet of the human skeleton ; a tortoise (alive, if possible) ; pictures showing the bony skeletons of the snake, a fish, and a frog ; the breastbone of some bird, or a picture of the whole skeleton.

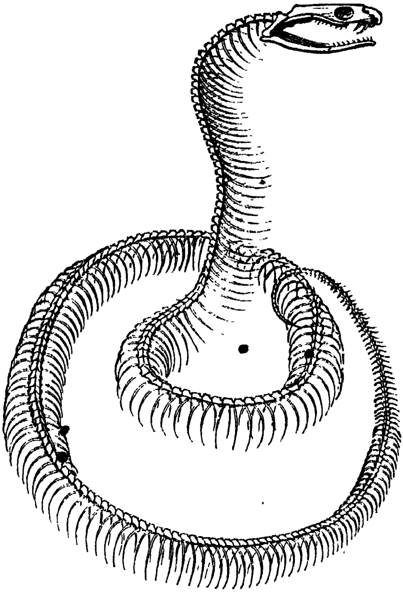


Fig. 6

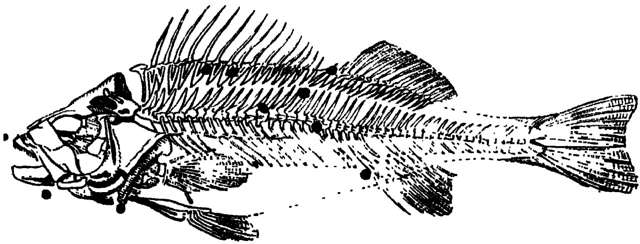


Fig. 7.

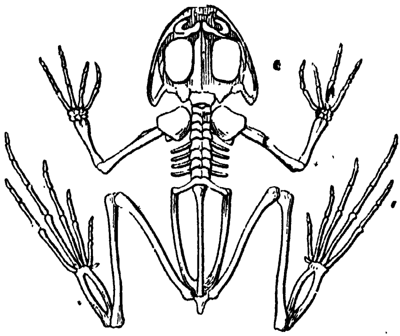


FIG. 8.

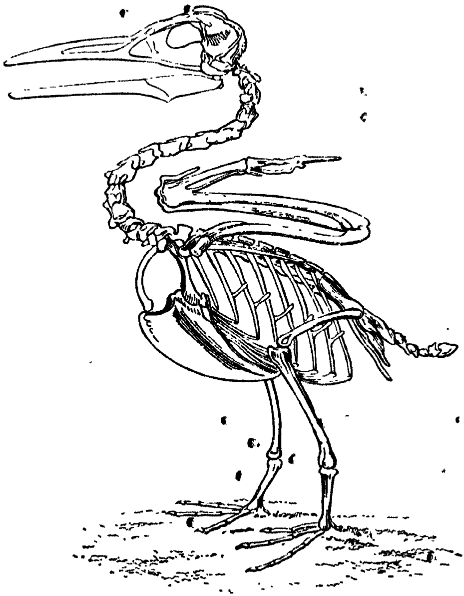


FIG. 9.

Lesson XXX

The wall-sheet of the human skeleton; pictures of the skeletons of a monkey and a cat; a prepared specimen of a mole, or a picture of one; pictures of a seal and a bear.

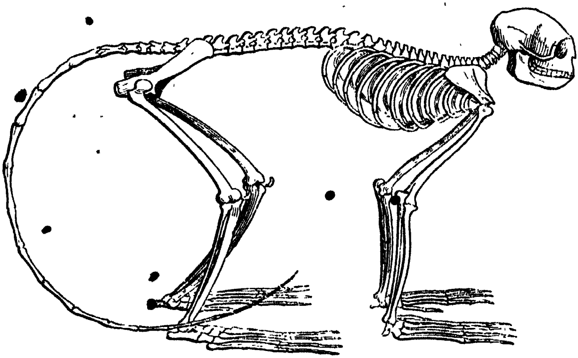


Fig. 10.

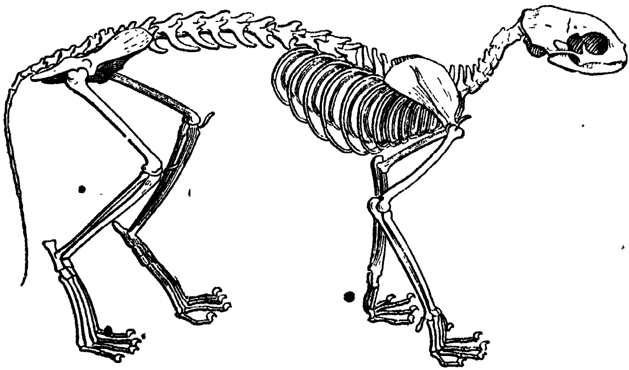


Fig. 11.

Lesson XXXI

The sheet showing the human skeleton, as in last lesson; sketches of the skulls of a dog, a seal, a rabbit, a sheep, a horse, with special reference to the teeth of each. In some of the cases (*e.g.* the dog and the rabbit) actual skulls might be

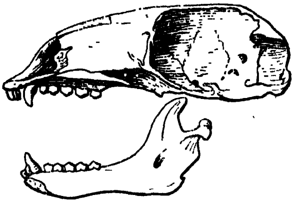


Fig. 12.—Dog.

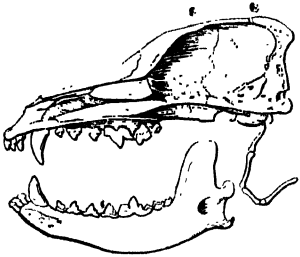


Fig. 13.—Seal.

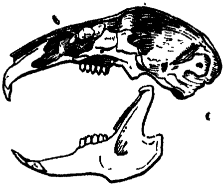


Fig. 14.—Rabbit.

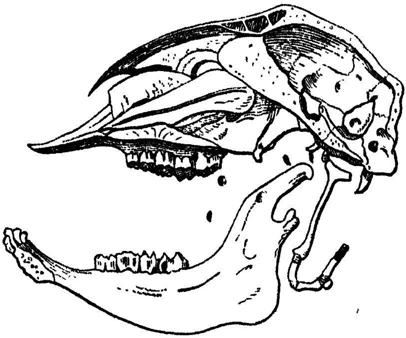


Fig. 15.—Sheep.

easily obtained. Provide also large molar-tooth of some kind; a rabbit or a squirrel (alive or stuffed); and pictures of as many of the animals mentioned as possible.

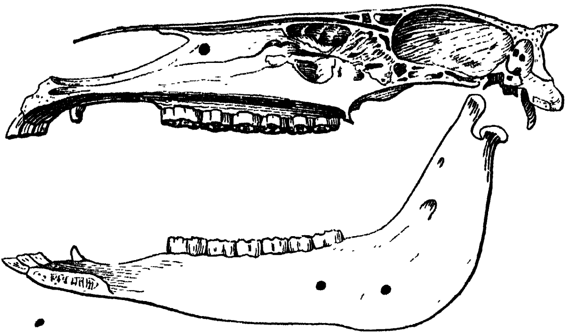


FIG. 16.—HORSE.

LESSON XXXII

A black-board sketch showing a magnified view of the sweat-glands; apparatus for showing the working of osmosis.

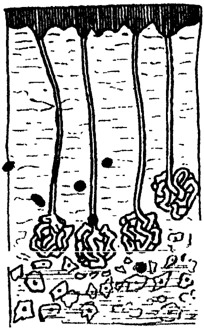


FIG. 17.

Lesson XXXIII

Specimens of horse-hair and hair-cloth. (Both the ordinary tail hair and that curled for stuffing purposes should be shown.) Specimens of fur, and a rabbit-skin ; a felt hat

Lesson XXXIV

Specimens of sheep's wool (raw and washed) ; a sketch showing wool fibres highly magnified ; specimens of Saxony or best Australian wool to compare with the English product ; pieces of broadcloth, flannel, and any other worsted material obtainable ; picture of a sheep, showing the different qualities of wool in a single fleece.

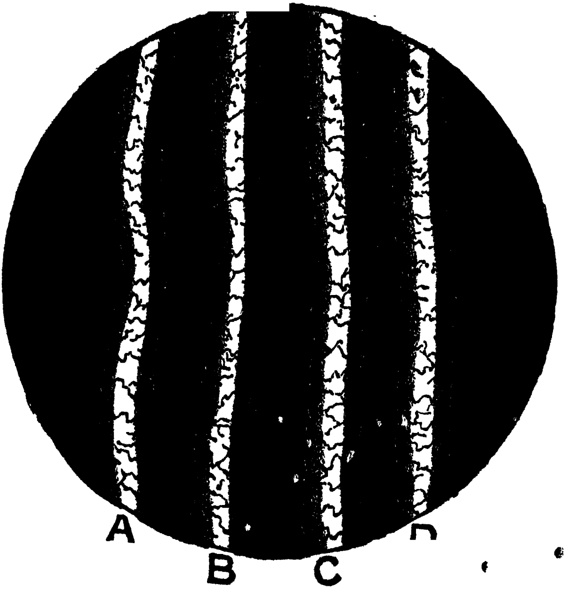


Fig. 18.—Merino Wool (450 Diameters).

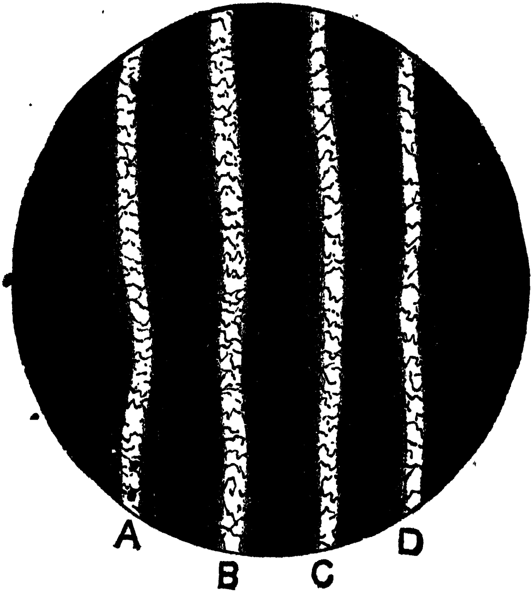


FIG. 19.—AUSTRALIAN WOOL (350 Diameters).

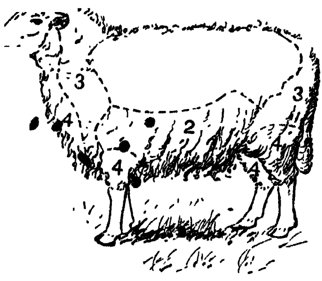


FIG. 20.—1, The most valuable part of the fleece; the other figures mark the various qualities in order.

STANDARD VI

Lesson I

Drawings or black-board sketches of a wind-mill and a water-mill in section; a fixed and a movable pulley. The fixed pulley may be screwed to a wooden stand on the table, or to a door or a cupboard. Some 1-lb., 2-lb., 4-lb. and 8-lb. weights.

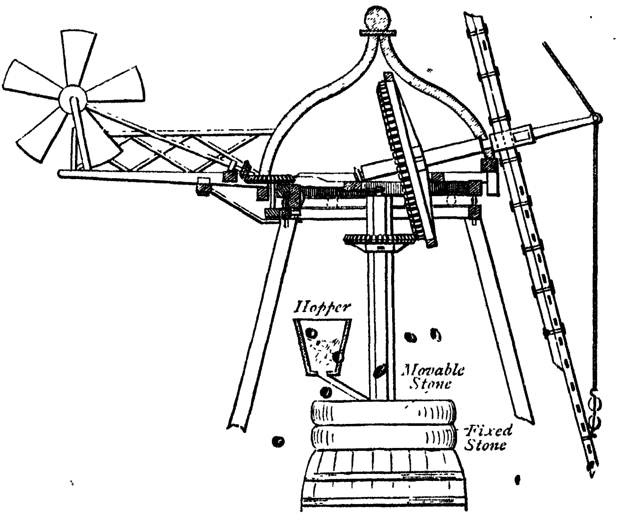


Fig. 21

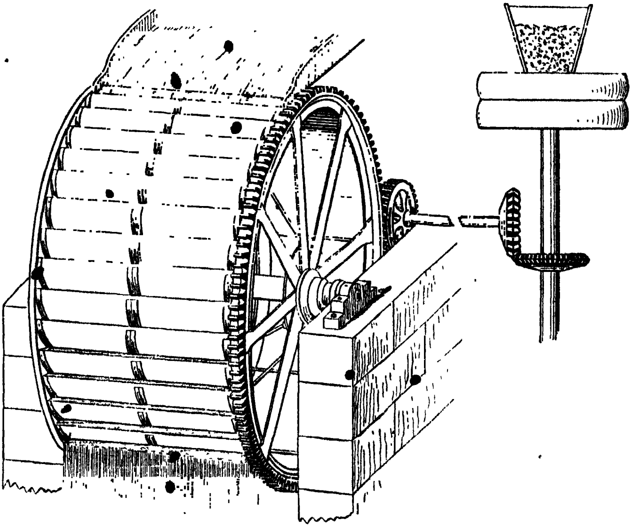


FIG. 22.

LESSON II

An iron crow-bar; a stout flat lath (*e.g.* a blind-stick) bore with gimlet-holes, as explained in the lesson; a set of ordinar

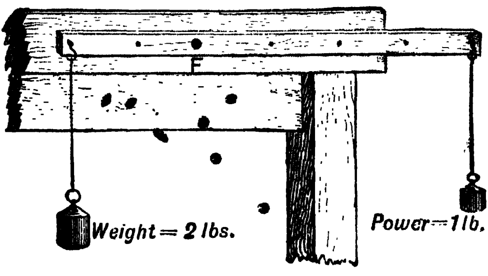


FIG. 23.

weights with rings for suspending them; a pair of scales, and a steel-yard; scissors; pincers; nippers; a claw-hammer.

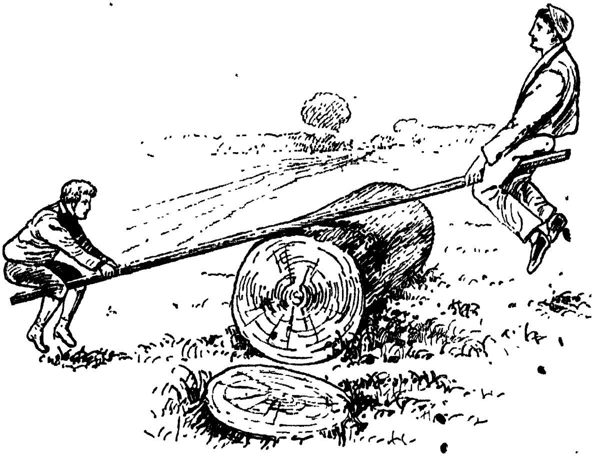


Fig. 24.

Lesson III

The lath-lever, and set of weights, as in Lesson II.; the fixed pulley attached to a cross-beam immediately above the lever; the crowbar; a small wheelbarrow; a pair of nut-crackers.

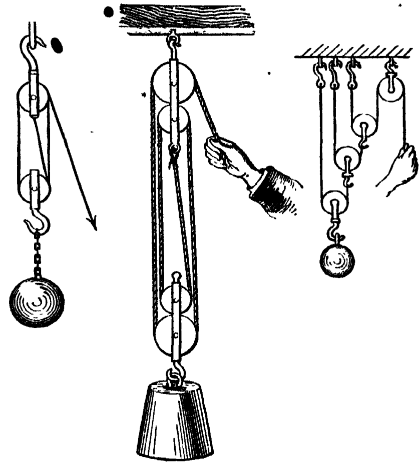
Lesson IV

The lever, pulley, and weights used in Lesson III.; a pair of tongs; black-board sketch showing the treadle of a sewing-machine with the parts attached to it.

Lesson V

A flat lath, similar to the one used in Lesson II., but about a foot long, having a hole drilled through its centre, and a cord attached to each extremity; a small wheel with the rim removed, and a wooden disc, as described in the lesson; the set

of weights; a fixed and a common block-pulley with cords; black-board sketches showing combinations of pulleys.



LESSON VI

The wooden disc of Lesson V.; a similar, but very much larger disc; cords for attachment to each disc, as explained in

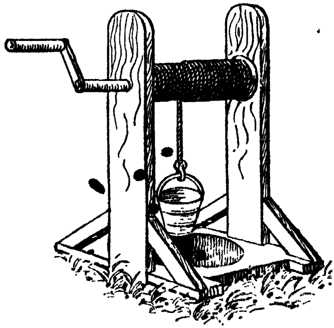


FIG. 26.

the lesson; black-board sketch of the discs in position; black-board sketch or picture of a well with windlass for raising the bucket; a capstan.

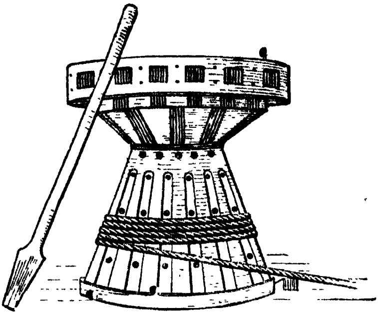


FIG. 27.

LESSON VII

A smooth polished piece of board, and a rough deal board; a small fixed pulley with cord and weights; one or two smooth polished objects.

LESSON VIII

The polished board of Lesson VII.; two blocks of hard wood, each cut in the form of an inclined plane; a wedge the same size; a large hammer.

LESSON IX

A corkscrew; a strip of white drawing-paper cut and marked in the way described in the lesson; a round ruler; some specimens of screws; a cork; an iron nut; a screw-driver; a picture of a screw-press.

Lesson X

A boy's popgun ; a sketch on the black-board showing the equal pressure of water ; a picture of the hydrostatic press.

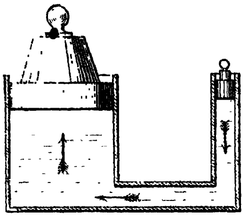


Fig. 28.

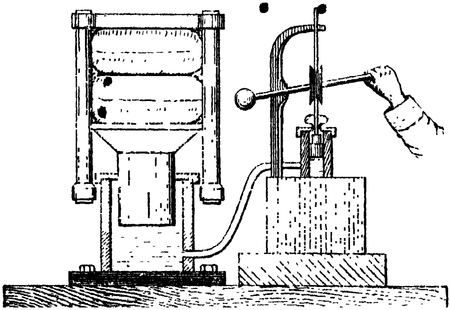


Fig. 29.

Lesson XI

The materials for making a fire ; a piece of charcoal ; the spirit-lamp, or Bunsen burner.

Lesson XIV

One or two test-tubes ; the Bunsen burner, or the spirit-lamp ; a small iron tray ; a basin ; some red oxide of mercury, hydrochloric acid, quicklime, and water.

Lesson XV

The bottle of potassium; a bowl of water; a glass flask, Bunsen burner, a small iron tray, and a retort-stand; some flowers of sulphur and a coil of fine copper wire.

Lesson XVI

Prepare beforehand and have in readiness for the lesson two or three jars of oxygen,—one of them, if possible, the stoppered bell-jar. Provide also pieces of carbon, sulphur, phosphorus; a spiral coil of very fine iron wire; a piece of rusty iron; a soda-water bottle, and the apparatus for generating oxygen and hydrogen, as described in Standard IV. course.

Lesson XVII

The bell-jar; a tray or bowl of water and piece of phosphorus; a taper; the apparatus for preparing oxygen.

Lesson XVIII

A pestle and mortar; a glass flask fitted with a funnel and a long bent delivery-tube; the spirit-lamp; two or three bottles, or gas-jars; some common salt, black oxide of manganese, and sulphuric acid; the deflagrating spoon; some phosphorus; some Dutch metal; a piece of sodium.

Lesson XIX

Some pieces of charcoal; lump-sugar; hot water; sulphuric acid; a saucer; a large basin; a jar of oxygen; some blue litmus.

Lesson XX

Some roll-sulphur and flowers of sulphur; a small tin plate; a test-tube; some fine copper wire; a jar of oxygen; the deflagrating spoon; some blue litmus.

Lesson XXI

Some phosphorus, potassium chlorate, liquid ammonia; a tin plate; the bell-jar; some blue litmus.

Lesson XXII

Some muriatic acid; test-tubes; blue litmus; some common salt and sulphuric acid; an iron spoon; a flask fitted with a bent delivery-tube; some gas-jars; a large bowl of water.

Lesson XXIII

A bowl of water; some red cabbage infusion; a piece of potassium; some caustic potash; blue and red litmus; olive-oil; test-tubes; nitric acid.

Lesson XXIV

A wall-sheet, or a good drawing, of the circulation; a hollow india-rubber ball.

Lesson XXV

The wall-sheet of the circulation; a black-board sketch of a vein slit open.

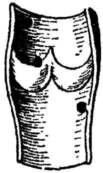
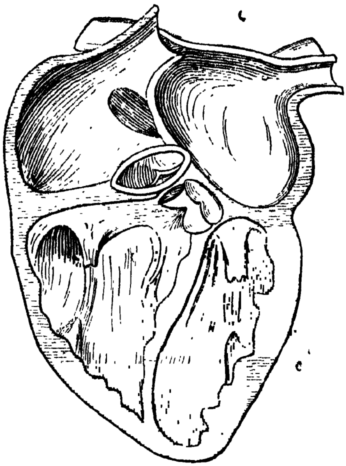


FIG. 80.

Lesson XXVI

Drawing on the black-board showing a section of the heart; the hollow india-rubber ball.



Lesson XXVII

A sheep's heart; a sharp, pointed knife.

Lesson XXVIII

A piece of looking-glass or polished metal; a tumbler; a piece of glass tubing; some lime-water.

Lesson XXIX

The wall-sheet of the human skeleton; black-board sketch showing heart and lungs in position; the apparatus for showing the working of osmosis, as explained in the lesson.

Lesson XXX

A recently-killed rabbit for experiment, as explained in the lesson, or a black-board sketch of the thorax.

Lesson XXXI

Some powdered starch, salt, and sugar; two or three tumblers of water.

Lesson XXXII

Some boiled starch; diagram or black-board sketch of the alimentary canal.

Lesson XXXIII

A bladder; an egg; a basin of water; some olive-oil; a gall-bladder; an oil-bottle; some common soda and hot water; a small piece of tripe or chitterlings; sketch of a villus.

Lesson XXXIV

Samples of the various corn grains; some fine wheaten flour, whole meal, bran, oatmeal.

Lesson XXXV

Samples of the pulse family; ground-nuts; sago; banana; dates; pictures of the bread-fruit and banana trees and the date-palm.

Lesson XXXVI

A potato; a carrot, turnip, or parsnip.

Lesson XXXVII

Specimens of nuts and fruits.

Lesson XXXVIII

Specimens of the various spices; some ground pepper, black and white.

Lesson XXXIX

Some raisins; some starch and sulphuric acid; the spirit-lamp and the evaporating-dish; picture of the sugar-cane; a beet; a picture of the sugar-maple tree.

Lesson XL

Some tea, cocoa, and coffee (ground); some boiling water; cups; specimens of the various sorts of tea; coffee-berries (raw and roasted); cocoa-nibs.

Lesson XLI

Some ripe currants, gooseberries, or grapes; specimens of malt and hops; picture of the growing hop; a retort and flask fitted air-tight; a bowl of ice; the Bunsen burner.

Lesson XLII

Specimens of calico, nankeen, muslin, corduroy, moleskin, fustian, velveteen, cotton hose, and lace; picture of the cotton-plant; some raw flax; specimens of linen, duck, diaper, damask, etc.; rope, cordage, canvas, floor-cloth; linseed and hemp-seed; raw jute.

Lesson XLIII

A piece of lean beef in spirits of wine, as described in the lesson.

Lesson XLIV

Some specimens of wool, bristles, horse, and cow-hair; black-board sketch or drawing on paper of wool-fibres highly magnified (as in Standard V. course, Lesson XXXIV.); specimens of various kinds of cloth, and other woollen and worsted fabrics.

Lesson XLV

Specimens of mohair, cashmere wool, alpaca, and camel's hair; pictures of the various animals named in the lesson.

Lesson XLVI

A prepared rabbit-skin, and one that has been merely dried; some oak-bark; specimens of leather; black-board sketch of the "crop," showing the varieties of quality in the single hide.

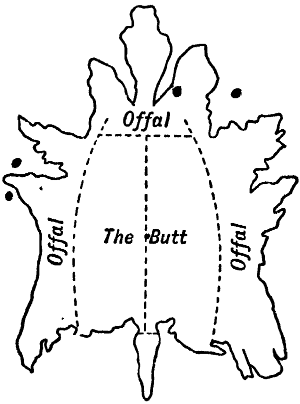


Fig. 32.

Lesson XLVII

A white kid-glove; a leather purse; the prepared rabbit-skin of last lesson; specimens of wash-leather, parchment, vellum.

Lesson XLVIII

A large shank or other bone properly cleaned; a picture of the skeleton of some animal; a hammer; a bone that has been

burned in a bright red fire; a bone that has been soaked for some days in muriatic acid solution; specimens of articles made of bone; bone-charcoal; bone-black.

Lesson XLIX.

Specimens of articles made of ivory and bone; a large molar-tooth of a cow or a horse; pictures of the African elephant, mammoth, hippopotamus, and walrus.

Lesson L

A bullock's horn, and (if they can be obtained) a stag's antlers; pictures of the stag and the reindeer; sketch of the head and horns of one of the antelope family; a piece of cow-horn; the spirit-lamp; a basin of boiling water.

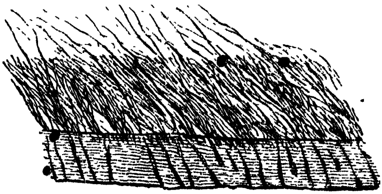
Fig. 33.

LESSON LI

A piece of gold-beater's skin ; some gut strings from a violin or other musical instrument ; specimens of glue, size, and gelatine.

LESSON LII

Specimens of fur ; pictures of fur animals ; map of the world ; black-board sketch of a piece of fur showing the over-hair ; a felt hat.



LESSON LIII

A piece of whalebone ; a black-board sketch of the skull of the baleen whale ; map of the world ; a picture of the Green-

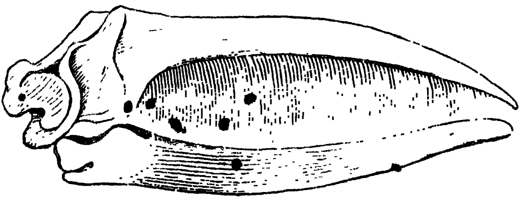


FIG. 35.

land whale ; a large iron spoon ; some fine sand ; the spirit-lamp ; a picture of the sperm-whale ; black-board sketch of the

tooth of the sperm whale; specimen of spermaceti; a picture showing the harpooner at work.

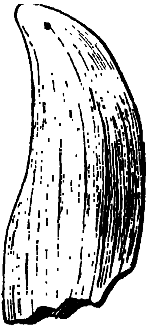


FIG. 36.

LESSON LIV

A piece of silk; some silk-worm moths, eggs, silk-worms, and cocoons; the silk-worm chrysalis.

INDEX

END OF VOL. III

Printed by R. & R. CLARK, LIMITED, *Edinburgh.*